IDRC-256e

Small Ruminant Production Systems in South and Southeast Asia

Proceedings of a workshop held in
Bogor, Indonesia, 6–10 October 1986

Proceedings Series

INTERNATIONAL DEVELOPMENT RESEARCH CENTRE
CENTRE DE RECHERCHES POUR LE DEVELOPPEMENT INTERNATIONAL
CANADA

87-02024/

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Postal Address: P.O. Box 8500, Ottawa, Ont., Canada K1G 3H9

Devendra, C.

IDRC. Regional Office for Southeast and East Asia, Singapore SG
IDRC-256e
Small Ruminant Production Systems in South and Southeast Asia : proceedings of a workshop held in Bogor, Indonesia, 6–10 October 1986. Ottawa, Ont. IDRC, 1987. xii + 414 p. : ill.

/Animal production/, /goats/, /sheep/, /mixed farming/, /small farms/, /South Asia/, /Southeast Asia/ — /feed/, /crops/, /research methods/, /economic analysis/, /animal diseases/, /case studies/.

UDC: 636.3(5) ISBN: 0-88936-493-1

Technical Editor: W.M. Carman

A microfiche edition is available.

IDRC-256e

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Editor: C. Devendra

Cosponsored by the
International Development Research Centre
and the
Small Ruminant Collaborative Research Support Program

Abstract This publication presents the results of a meeting held in Bogor, Indonesia, 6-10 October 1986, that focused specifically on the assessment of small ruminant production systems in South and Southeast Asia. It considered the prevailing circumstances, the innovations, and the strategies that are pertinent for stimulating increased productivity from goats and sheep. The present patterns of production were examined in detail with reference to characteristics of the small farms, existing management methods, and nature and components of the production systems. These systems include extensive systems, systems combining arable cropping, and systems integrated with tree cropping. The discussion of the systems were further highlighted by country case studies, issues and policies that considered the available production resources, especially the genetic and feed resources available, constraints to production, and potential means to achieve desirable improvements. An important session was devoted to examining research methodology, strategies for development appropriate to individual systems, and a conceptual framework for on-farm economic analysis. Together, these discussions enabled a definition of research protocols and the priorities for future direction that are likely to have a major impact on productivity from small ruminants.

Résumé L'ouvrage présente les conclusions d'une réunion tenue à Bogor, en Indonésie, du 6 au 10 octobre 1986, portant sur l'évaluation des systèmes de production touchant les petits ruminants en Asie du Sud et du Sud-Est. On y a brossé un tableau de la situation actuelle, des innovations et des stratégies susceptibles d'accroître la productivité dans l'élevage de la chèvre et du mouton. On a examiné en détail les méthodes actuelles de production dans la perspective propre aux petits exploitants, les éthodes actuelles de gestion, le type de systèmes de production et leurs éléments. Il s'agit ici des systèmes extensifs, des systèmes associant la culture des terres, et des systèmes intégrant la sylviculture. Les discussions ont été étayées d'études de cas, de problèmes et de politiques émanant des divers pays et portant sur les ressources disponibles pour la production, spécialement les ressources génétiques et fourragères, les contraintes à la production, et les possibilités d'amélioration qui existent. Une importante session fut consacrée à l'examen de la méthodologie de la recherche, des stratégies de développement convenant à chaque système, et d'un cadre conceptuel pour l'analyse économique des activités sur le terrain. Toutes ces réflexions ont permis de définir des plans de recherche et d'établir les priorités qui, dans l'avenir, auront vraisemblablement un impact majeur sur la productivité liée à l'élevage des petits ruminants.

Resumen Esta publicación presenta los resultados de la reunión celebrada en Bogor, Indonesia del 6 al 10 de octubre de 1986, cuyo temp principal fue la evaluación de los pequeños sistemas de producción de rumiantes en el

Sur y Sureste asiático. En la misma se analizaron las circunstancias imperantes, las innovaciones y las estrategias pertinentes para estimular la mayor productividad del ganado caprino y ovino. Se examinaron detenidamente los patrones actuales de producción con respecto a las características de las pequeñas granjas, a los métodos de manejo existentes y a la naturaleza y componentes de los sistemas de producción. Estos sistemas incluyen sistemas extensivos, sistemas que combinan el cultivo de tierras arables y sistemas integrados con plantaciones de árboles. La discusión de estos sistemas estuvo acompanada del análysis de etudios de casos en diferentes países, así como de problemas y políticas relacionados con los recursos de producción disponibles, especialmente los recursos genéticos y alimenticios disponibles, las limitantes de la producción y los posibles medios para obtener las majoras deseadas. Una importante sesión estuvo dedicada a examinar la metodología de las investigaciones, las estrategias para el desarrollo apropiadas para cada sistema individual, y un marco conceptual para la realización de análisis económicos en las granjas. En su conjunto, estas discusiones permitieron definir los protocolos de investigación y las prioridades para el futuro, que probablemente habrán de tener importantes repercusiones sobre la productividad de los pequeños rumiantes.

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ACKNOWLEDGMENTS

The International Development Research Centre (IDRC) wishes to thank Dr I. Gunawan Sattari, Director General, Agency for Agricultural Development (AARD), Drs Jan Nari and M. Rangkuti of the Central Research Institute for Animal Sciences (CRIAS), Dr Peter Kompiang, Director, Research Institute for Animal Production (RIAP), and Dr Purnomo Ronohardjo, Director, Research Institute for Veterinary Science (RIVS), for their support. Special thanks is extended to the several scientists and institutions who participated in the workshop and contributed to the realization of this publication. Support of the following international organizations in funding the participation of their staff is gratefully acknowledged: the Small Ruminant Collaborative Research Support Project (SR-CRSP) of the United States Agency for International Development (USAID), Winrock International, and the Australian Development Assistance Bureau (ADAB). Summaries of individual sessions and group discussions were presented by the following participants: Drs W.A. Pattie, J.G. Holmes, R. Gatenby, G.E. Bradford, D.A. Ivory, W.L. Johnson, and P. Amir. The final recommendations and overall synthesis were admirably presented by Professor I.E. Coop.

FOREWORD

Small ruminant goats and sheep are very important but neglected resources in the developing countries. Because of their large populations, small ruminants make a significant contribution to the economy and food supply in these countries. They are closely identified with the poorest people in pastoral systems ranging from the arid and semi-arid tropics to complex crop-livestock systems in the humid tropics. Their greatest value in farming systems is associated with small size, low individual costs, rapid turnover, and the conversion of feed resources not directly eaten by man: natural pastures, fallow grazing, browse, and crop residues.

Despite these apparent advantages, resource allocation in general and research on increasing food production from small ruminants has been quite inadequate in the developing countries. A review by the Technical Advisory Committee (TAC) of the Consultative Group for International Agricultural Research (CGIAR) and projections up to the year 2000 suggest that the annual increase in demand for sheep and goat products and for milk from all animals is growing faster than for any other food commodity. Low production has been constrained by limited resources, inadequate research support, and, in many developing countries, lack of a priority definition focusing specifically on increasing productivity from goats and sheep.

To address these issues, an important new initiative in the Crops and Animal Production Systems Program (CAPS) within the Agriculture, Food, and Nutrition Sciences Division is increased attention to support research and development of small ruminants. The objectives include research on the complex interactions between the environment and animals, assessment of the value of many outstanding breeds, current problems of producers and consumers, and the development of institutional and research capacity. The strategy is to provide specific research and institutional support for topics that are likely to have a major impact on small ruminant productivity, especially of milk and meat, and improve the socioeconomic condition of the rural peasants.

Recognizing this initiative and the increasing focus on production systems research, the International Development Research Centre (IDRC) was pleased to be able to organize the present workshop in association with the Small Ruminant Collaborative Research Support Program (SR-CRSP) of the United States Agency for International Development (USAID) and the Australian Centre for International Agricultural Research (ACIAR). The choice of subject matter and speakers in examining the various issues related to small ruminant production systems in South and Southeast Asia is particularly appropriate at this time in ascertaining specific problems, research requirements, potential technological interventions that can increase the stability of small farm systems, and the generation of new knowledge to sustain further progress.

The development of small ruminants is especially significant in integrated systems in the region. It also concerns issues of sustainability, including their wider use in agroforestry systems with complementary advantages of forage production, supply of fuelwood, improvement of soil fertility, and permanent soil cover and economic land use.

The primary workshop objective was to examine small ruminant production systems in detail against the background of country case studies and issues and problems related to the Asian environment, since these topics have never been exhaustively discussed. These discussions led to a definition of important research protocols, and a framework for further research thrust and strategies for the future. It is envisaged that this workshop will stimulate research in individual countries and, therefore, increase the contribution of small ruminants. It is also hoped that the workshop will strengthen the regional cooperative network of the Asian and Pacific region established by the Food and Agriculture Organization (FAO) to advance goat and sheep production in the region.

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INTRODUCTION

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This workshop centred on two main issues: the resource base and the research focus on small ruminant production systems in South and Southeast Asia. Concerning the resource base, the South and Southeast Asian region is endowed with a diversity of ruminant species; this region also has a very large proportion of the total population of small ruminants in Asia (23-53%). With this strong genetic base, goats and sheep together rank second to buffalo in terms of numerical importance, with a bewildering variety of outstanding breeds that demonstrate the ability to adapt, survive, and reproduce within the climatic extremes of the region. A unique feature of these breeds is their multifunctionality in South and Southeast Asia, where they perform a wide range of important services for the millions of peasant farmers and landless poor. Within complex small farm systems, where the emphasis is crop production, goats and sheep are essential to the farming community and the utilization of scarce resources.

The need for a sharper research and development focus that addresses issues of increased productivity and contribution of small ruminants is clear; however, this need can only be realized through several prerequisites. First, the limited knowledge base must be fortified with respect to the climatic extremes of the region, the characteristics and responses of a wide variety of genotypes in various environments, the different types of production systems, scarce production resources (especially feeds), and major constraints to production. Second, a basic understanding of the prevailing patterns of production and their inherent limitations enables a consideration of the priorities and resources necessary, including official support, that can increase productivity. Third, it is then feasible to define and formulate a development strategy with appropriate resource allocation that ensures a major impact on small ruminant production.

At present, production systems are poorly understood and this problem is exacerbated in South and Southeast Asia in the face of both annual and tree crop systems, with their differing profiles and requirements for integrating small ruminants to advantage. The main tree crops are coconuts, oil palm, and rubber, grown on a land area of approximately 20 x 10^6 ha. This area has a vast potential for integration with small ruminants, which can significantly contribute to the economy and food supply in the region.

This scenario provided a compelling basis for organizing a workshop to thoroughly examine and discuss all aspects of small ruminant production systems. The current understanding of prevailing production systems and the promotion of collaborative multidisciplinary efforts between the participants and the institutions was also discussed. The decision to organize this meeting has its origins in a discussion with my friend and colleague, the late Dr David Robinson, former Program Director of the Small Ruminant Collaborative Research Support Program (SR-CRSP) of the United States Agency for International Development (USAID), in July 1985, who promptly endorsed its value. Later, the Australian Centre for International Agricultural Research (ACIAR) also decided to participate, resulting in a tripartite sponsorship. The meeting was attended by 44 participants from 15 countries.

The workshop was structured into four main sessions. The first session analyzed the various aspects and characteristics of small ruminant production systems. The second session consisted of case studies from nine countries in the region and focused on the different types of production systems, problems, and issues. These studies were particularly invaluable in illustrating the varying patterns of management, levels of production, extent of research support, major issues requiring attention, and opportunities for improvement. The third session examined, against the background of the country studies, possible strategies and research methodology, including a framework for economic analysis of on-farm trials appropriate to small ruminant production. The final session, possibly the most important, was devoted to working group discussions that exhaustively addressed areas of research priority, research protocols, resource allocation, and the identification of future research direction to intensify the development of small ruminants. The final objective was to define practical and technological improvements that could be adapted to the needs of small farmers and were applicable to the various environments in South and Southeast Asia. These interventions should match the small farmers' resources and, when introduced slowly, ensure income stability and low risk.

There were two additional issues discussed during the workshop. One concerned the dissemination of print and nonprint materials, including accession, concerned with small ruminants. The question was whether this kind of activity was beneficial, and if there was a need to respond to innovative approaches that might include, in addition to information dissemination, a data bank for goat and sheep breeds in the region. The meeting discussed the objective of the Food and Agriculture Organization (FAO) to produce an inventory of all ongoing projects and the possibility of initiating in-country integrated training courses for extension staff in practical on-farm development strategies.

The workshop provided a valuable forum for the participants in aiding communication at a variety of levels. Considering the objectives, the issues addressed, and the achievements, the results of the workshop auger well for the future of small ruminant production in South and Southeast Asia.

KEYNOTE ADDRESS:
SMALL RUMINANTS IN INDONESIA

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It is my pleasure to welcome all of the participants of the workshop on Small Ruminant Production Systems in South and Southeast Asia held here in Bogor. I am happy to see your eagerness to participate in this workshop to review and discuss the status of all matters about small ruminant production in the region.

In Indonesia, we have a total of 12 million sheep and goats. The animals are kept in small numbers by hundreds of thousands of small farmers for a number of reasons. For farmers, the animals are a living savings account that can easily be converted into cash at any time. Small ruminants are an important means to increase the economic value of resources in farmers' hands such as abundant forages and family labour. Whatever the reasons farmers may have for keeping their animals, small ruminants are responsible for about 20% of farmers' total annual income.

Sheep and goats fit well into present agricultural systems in Indonesia. Nothing is perfect, however, and the farmers encounter problems with rearing sheep and goats. Some of these problems include disease, low digestibility of available foods, toxic compounds in foods, long parturition intervals, high mortality of lambs and kids, and high air temperature and humidity. The problems faced by farmers are not constant but change as the economic conditions in villages change. For instance, the development of a factory that produces an edible by-product challenges the local farmers: can they successfully utilize this by-product by feeding it to their animals?

In this country, small ruminant production must be improved within the context of farming systems. This calls for vast and intensive research of related disciplines. In this respect, workshops such as this will be valuable. A lot of research has to be done to improve small ruminant production in South and Southeast Asian countries. Mutual and intensive cooperation among research scientists working for the development of the region will be a great help in realizing the objective.

Bogor is world famous for two reasons. First, it holds the world record for the greatest frequency of thunderstorms and I expect you will experience some during your stay here. Second, Bogor is famous for its botanical garden, which was established in 1817 by Sir Stamford Raffles. The local name for the botanical garden is "kebun raya."

The city of Bogor has grown up around the botanical garden, and Bogor is in many ways the hub of agricultural research in Indonesia. We are hosted this week by the Central Research Institute for Animal Sciences (CRIAS). There are also numerous other research institutes in Bogor: the Research Institute for Food Crops, the Research Institute for Estate Crops, the Research Institute for Freshwater Fisheries, and the Research Institute for Spices and Medicinal Plants, to name but some.

Bogor has three universities: Institut Pertanian Bogor, Universitas Pakuan, and Universitas Ibnu Chaldun. Institut Pertanian Bogor is the National Agricultural University. It is a highly respected university taking in students from throughout Indonesia to study a whole range of agricultural topics.

In Bogor, we also have the National Biological Institute, the National Library for Agricultural Sciences, the Herbarium, the Zoological Museum, and the Ethnobotany Museum. To the south of Bogor in Tajur we have Biotrop, the Southeast Asian Regional Centre for Tropical Biology, and in Ciawi we have IPLPP, a national centre for training staff for the agricultural services.

It would take too long for me to tell you about the activities of all these institutes. Let me just tell you a little about the Research Institute for Animal Production and the Veterinary Research Institute. Both these institutes come under an umbrella entitled the Central Research Institute for Animal Science. The director of this Institute is Dr Jan Nari. The director of the Veterinary Research Institute is Dr Purnomo

Ronohardjo. The director of the Research Institute for Animal Production is Dr Putu Kompiang.

The sheep and goat research program at the Research Institute for Animal Production (BPT) is extensive. Most research is conducted using the farming systems approach. The research scientists themselves have close contact with the farmers. This enables scientists to understand the farming system and to identify problems faced by the farmers. Research is then carried out in the laboratory or experimental station. Before new technology can be given out to the farmers by the extension worker, it must be tested on the farm. This is done by scientists going back to the small farmers and monitoring the success of the new technology in a small farm situation. Both the technological aspects and the socioeconomic aspects of the improvement must be suitable; it is no good having a technology that is not acceptable to the farmers. So, within BPT and Balitvet (the Veterinary Research Institute) we have scientists who are farming systems specialists, nutritionists, breeders, socioeconomists, virologists, bacteriologists, parasitologists, mycologists, and toxicologists; all of them are involved in sheep and goat research.

Facilities for research in BPT are located in Jalan Raya Pajajaran, Bogor, and in the Ciawi campus. Both these locations have offices, laboratories, and animal houses. There are also animal breeding stations at Cicadas and Cilebut for sheep and goats, respectively, and much work is conducted in villages throughout the Bogor district and in other parts of Indonesia.

Many Indonesian scientists are involved in sheep and goat research, but we are also fortunate to have had inputs from several overseas projects during the past few years. These are the Australian project with staff located at BPT, Ciawi. The current team leader is Dr Bruce Clark. In BPT, Bogor, we have expatriates working on the Small Ruminant Collaborative Research Support Project (SR-CRSP) and the Applied Agricultural Research Project, both projects being funded by the United States Agency for International Development (USAID). The Project Liaison Officer of the SR-CRSP is Dr Luis Iniguez. In Balitvet, we have expatriate scientists working on Australian- and British-funded projects. The leader of the Australian project is Dr Alan Wilson.

The objectives of this workshop are many. We hope to review the current production systems for sheep and goats, to identify the constraints that limit production, to suggest appropriate research programs, to formulate research protocols and work plans, to assess the requirements of research inputs, and to promote collaborative research and development effort between the participating institutions.

To improve production research is a prerequisite. I believe that this workshop will not only benefit all of you as individuals, but also will benefit farmers of the South and Southeast Asia. Over the next few days, all of you will devote much of your time and energy to this workshop, but I hope that you will also have time to enjoy your stay in this country.

On this occasion I would like to express my special thanks to IDRC, SR-CRSP, and ACIAR for their cosponsorship, and to CRIAS for hosting this workshop. I would also like to acknowledge the special efforts of Dr C. Devendra in organizing this workshop. Finally, I would like to declare this workshop officially open.

Session I

Production Systems

CHARACTERISTICS AND SOCIOECONOMIC ASPECTS OF SMALL RUMINANT PRODUCTION SYSTEMS: AN ANALYTICAL FRAMEWORK

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Abstract *Small ruminant production systems are generally found as a secondary component in mixed farming systems. Crop by-products, kitchen wastes, and crop residues are often important feed supplements. The use of these feeds to supplement grazing on public lands and different sharecropping arrangements make it possible for very small farmers and even landless farmers to have small ruminants. Because they are a subsidiary enterprise and because of the interactions with other components on mixed farms, sheep and goats should usually not be analyzed as an independent commodity but rather as an integral component of a larger system. Often research must be done to develop an analytical framework that includes the key components of this larger system. A microcomputer spreadsheet template can be used to develop a quantitative description of the inputs and outputs of these key components. The component-level templates can then be combined by linking common inputs and outputs. This type of analytical framework was used successfully in a small ruminant research project in western Kenya. Templates for different feed production areas, feed storage, and cattle, sheep, and goat herds over were combined to form an analytical framework that was used to identify potential feed technology and potential improvements in the goat component of the mixed farm systems.*

An important difference between agricultural production systems research and traditional commodity and discipline-focused research is that agricultural systems research is directed at a target system. Small ruminant production systems research, like other development-oriented research, is evaluated by its potential impact on development. This requires an understanding of the linkage between the system that is the subject of physical and biological experimentation (e.g., a goat herd) and the socioeconomic system that is the target for development (e.g., a geographic region).

Farm systems are a key intermediate link between livestock-level phenomena and regional-level phenomena. The fact that in most cases small ruminant technology must be selected or modified to fit into a farm system, and that its adoption is expected to have an impact on regional development, has important implications for research and methodology. Not only must biological research be done to design and evaluate new technology, but multidisciplinary research must be done to develop a framework linking the phenomena that are the subject of experimentation and the phenomena that are the targets for developments.

The first section of this paper describes the general socioeconomic characteristics of small ruminant production systems and the rationale for separating activities needed to develop an analytical framework from activities involving the actual design and evaluation of livestock technology. The second section describes a farm system template (a generalized analytical framework) and a process to develop a framework based on linking farm system component templates. The term "framework" rather than the term "model" is used because a key premise of this paper is that a set of descriptive interrelated data (i.e., a framework) is a useful tool in and of itself. The third section of this paper is a case study describing small ruminant research in Kenya that illustrates how the templates can be applied to a specific farm system to develop an analytical framework. The fourth section is a discussion of how an analytical framework can be used to integrate socioeconomic and biophysical factors in the design and evaluation of technology.

SOCIOECONOMIC CONSIDERATIONS

Small ruminant production is typically a small-scale farmer activity attracting minimum investment in housing, feed, and health care, and is, therefore, largely sustained by the potential of the indigenous breeds themselves. Sharecropping, which reduces cash/capital requirements even further, is common in most countries. In a sharecropping system, borrowers of breeding stock share offspring with owners and meanwhile incur all maintenance costs. The system makes it possible for people with no stock or capital to purchase stock to enter small ruminant production or increase their flock size. At the same time, producers with larger flocks distribute the cost of their own labour and spread their risks.

In most countries, crop by-products, kitchen wastes, and crop residues are important feed supplements for small ruminants, but these are not fed systematically. The amount fed and its significance varies significantly between producers and according to season. In general, the actual and potential role of these supplements appears minor. Under confinement, feed is collected from surrounding vegetation. In most countries, the end product of the system is meat and milk production. Livestock products are, in general, kept for sale, although they are also consumed at religious festivals and during ceremonies (births, deaths, marriages, graduating apprentices, etc.).

Within the general socioeconomic and biological characteristics of small ruminant production systems discussed in the foregoing, three distinct types of management can be distinguished: free roaming (extensive) or herding, tethering, and confinement of animals. In most of Africa, the system of production of both sheep and goats is extensive. Two exceptions have been identified to date, the southeastern parts of Nigeria and the Peoples Republic of Benin, where both sheep and goats (at times mixed flocks) may be confined. In Asia, tethering and confinement are more common. Under confinement, which is associated with more intensive cropping and land scarcity (like Java), more investment is required, if only to provide feed. In the Latin American lowlands and the Caribbean, sheep are free ranging and tethered, but goats are usually tethered near the farm households or in urban settings.

Sheep and goats in developing countries are generally found as a secondary component in mixed farming (food crop-tree crop-livestock) farming systems. With the exception of pastoral systems (where most income is derived from keeping livestock on natural forage), sheep and goat flock sizes tend to be small. Because small ruminant production is usually a subsidiary (minor) farm enterprise, it provides a comparatively small proportion of total income, although the proportion increases for smaller farmers.

Because they are a subsidiary enterprise and because of the interaction with other components of mixed farms, sheep and goats should usually not be analyzed as an independent commodity but rather as an integral component of a larger production system. For this reason, a systems approach has proven to be useful. The analytical framework described in the next section is a tool that can be used in the analysis of small ruminant production systems and the larger socioeconomic systems into which the small ruminant production system must fit.

INTEGRATING EXPERIMENT AND DEVELOPMENT-LEVEL PHENOMENA

One of the problems faced by scientists on production systems research teams is deciding which of many alternatives to choose as a research priority. Often the first phase of implementation is a reconnaissance to identify production constraints, but in many cases the "constraints" identified are a mixture of observations that cannot be addressed without more analysis (e.g., soil "fertility") and factors that cannot be solved by biological research (e.g., poor transportation in the rainy season). Menz and Knipscheer (1981) have termed this the "notional" stage of technology evaluation.

In the 1st year of most production systems projects, the linkage between biological experiments and potential development impact is usually justified by "common sense" statements (e.g., higher milk production could mean higher farmer income). The results of these experiments are usually evaluated on the basis of the scientists' perceptions (e.g., land is assumed to be the limiting farm resource); seldom are farmers' values (e.g., return per seed input or return to labour) explicitly considered. What is needed is an analytical framework that explicitly takes into consideration potential development impact, includes information that links research and extension and is in a format that is flexible enough for continuous updating, integrates different disciplines, and functions as a guideline for the selection of technology to be tested.

AN ANALYTICAL FRAMEWORK

Farm systems are composed of biological enterprises (crop or livestock production systems or both) and household enterprises (postharvest storage, nonagricultural activities, etc.) to which farmers must allocate farm-level resources on the basis of expected returns (quantities as well as expected variance). At the same time they must consider potential off-farm uses of land, labour, and capital. Farmers select technology by evaluating how it fits into the total farm system. For this reason and because farm systems are intermediate between the phenomena that are the usual subject of biological research (e.g., livestock herds) and the phenomena that are the usual target for development (e.g., geographic regions), farm system descriptions and farm-level models are an ideal framework for ex ante selection of potential technology for biological experimentation and ex post evaluation of experimental results.

The wide range of potential types of farm systems makes it impossible to develop a farm system analytical framework that can be used in all situations. Clearly, each production systems team must develop a farm-level analytical framework that reflects the salient characteristics of the predominant type of farm system in the area selected as a development target. Although farm systems are all different, it is impossible to develop a general farm system template that can be used to develop a specialized farm system-level analytical framework. It is important to note that for an analytical framework to be useful it need not include a quantitative description for the entire farm system, in most cases detailed quantitative information is needed only for the key farm system components.

The development of an analytical framework can be visualized as a two-phased process that involves different steps occurring within each phase.

- Phase I: Development of a qualitative farm-level framework by identifying the key components of the farm system; and identifying the pathways that link the key components of the farm system and the farm system inputs and outputs.

- Phase II: Development of a quantitative farm subsystem framework by identifying the farm component(s) targeted for research and the other farm components that directly interact with it (them); development and use of data collection instruments to describe the inputs, outputs, and state of key farm components; and integration of the quantitative component descriptions to form a farm subsystem analytical framework.

The farm-level and farm component-level templates described in the following are essentially input/output models, and there are inherent dangers associated with the deterministic characteristics of this type of model that must be taken into consideration. The model, however, lent itself to easy adaptation into a linear programing model or any structural model. For economic analysis, linear programing has proven a cost-effective tool for evaluation of new farming systems technologies as it allows interaction between farm production enterprises, quantifies the impact of limiting factors by shadow prices, and can be used for simalization. It is a model that maximizes the economic returns to a combination of resources rather than individual resources (e.g., land).

In the two-phase process just described, the quantitative framework is formed by combining component-level templates. This is done by assuming outputs from one component are inputs to another. The data collected for the components (e.g., the smal ruminant enterprise), however, are often collected at different times and under different conditions. When the templates are combined it is easy to forget that the individual numbers are not nearly as deterministically related as the framework implies.

The two-phase process also implies that framework development can be done by following a simple sequence of activities. Modeling, however, is as much an art as a science. No-one would presume to tell an artist that it is better to start by painting the background and later adding the detailed foreground, or better to start with the detail and then add the background. In the same way, some modelers start with the whole and proceed to the components; others start with key components and the proceed to the whole. The development of a farm-level analytical framework can begin at the individual crop or livestock commodity level and proceed to the cropping system or livestock production system level and then to the farm level; or the process could begin at the farm level and move down to the production system and commodity levels; or a research team could begin at the farm and the commodity level at the same time. Regardless of where a framework development process begins, it should end with a description that includes enough quantitative detail to allow production system-level changes to be selected and evaluated.

Qualitative Farm System Framework

Figure 1 is a generalized qualitative diagram of a farm system. Most farms will not have all the components identified in the diagram. For example, to develop the diagram, it was assumed that farms can include many types of crops, forage, and herd components; in reality, many farms do not have all three types of production systems. To develop the diagram, it was

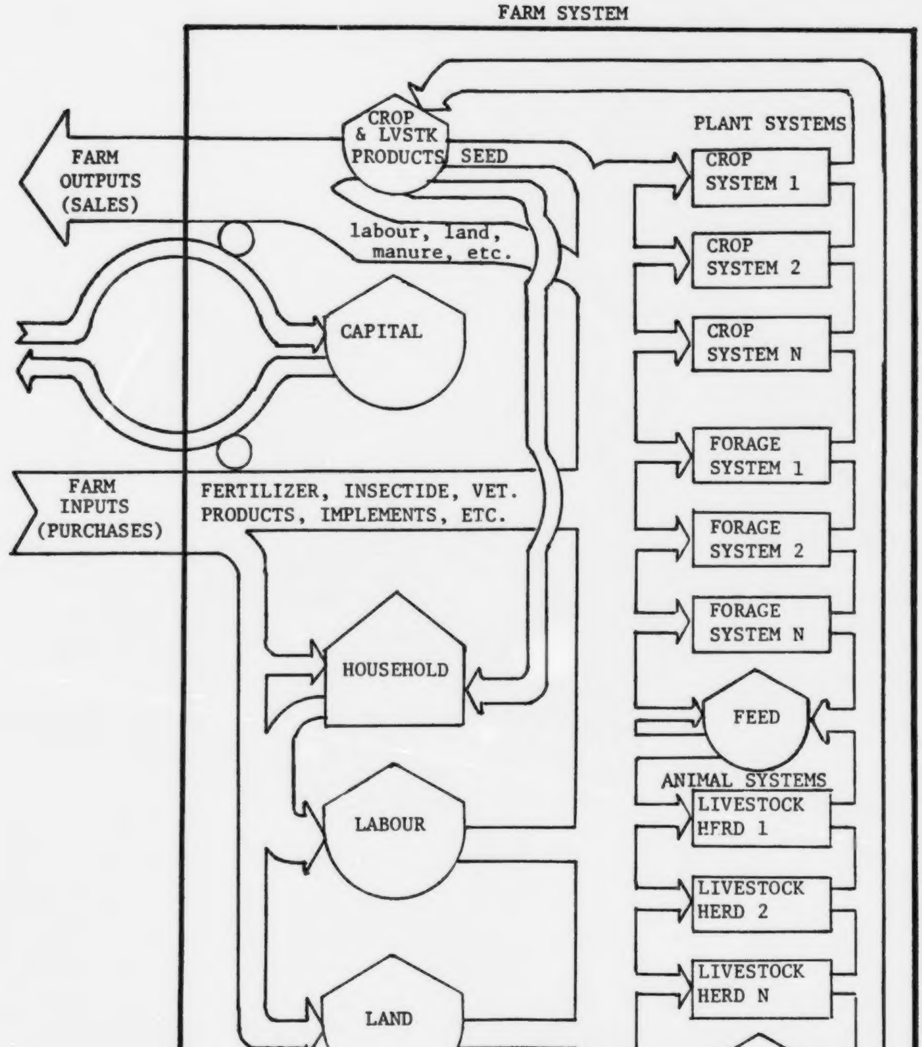
FARM SYSTEM
CROP & LVSTK PRODUCTS
SEED
PLANT SYSTEMS
FARM OUTPUTS (SALES)
labour, land, manure, etc.
CAPITAL
CROP SYSTEM 1
CROP SYSTEM 2
CROP SYSTEM N
FORAGE SYSTEM 1
FARM INPUTS (PURCHASES)
FERTILIZER, INSECTIDE, VET. PRODUCTS, IMPLEMENTS, ETC.
FORAGE SYSTEM 2
FORAGE SYSTEM N
HOUSEHOLD
FEED
ANIMAL SYSTEMS
LABOUR
LIVESTOCK HERD 1
LIVESTOCK HERD 2
LIVESTOCK HERD N
LAND
MANURE
PRECIPITATION SOLAR RADIATION
ANIMAL TRACTION

Fig. 1. A generalized farm system diagram that identifies potential farm components, pathways among components, and input and output flows.

assumed that farms can have the following types of components: a household; land, labour, and cash resource pools; crop and livestock product storage; crop, forage, and herd production systems (subsystems); and feed and manure storage.

The pathways that can connect these various types of components are also shown in the farm system diagram. Once again, the diagram illustrates all possible linkages, all of which are not likely to be found on one farm. For example, the farm depicted in the diagram has crops, forage, and herds linked by direct flows of forage and manure as well as by indirect linkages through storage components. In reality, many farms will not have all of these types of crop-livestock interactions.

In addition to the pathways that connect farm production systems, the diagram also includes flows from land and labour resource pools to the various production systems. The diagram also includes that flows of land and labour from off-farm to the resource pool (farmer renting someone else's land and acquisition of off-farm labour) and flows of land and labour fro the resource pools off the farm (farmer renting his or her land, family labour, off-farm employment).

Cash (liquid capital) flows in directions opposite to purchased inputs (including household and crop and livestock production inputs) and to income-generating activities such as the sale of products or rent of resources (e.g., off-farm employment). In the farm diagram presented in Fig. 1, this relationship between cash flows and other farm inputs and outputs is depicted by a "wheel" linking cash to "farm inputs" and "farm outputs."

Cash management affects all farm enterprises. Cash availability over time affects a farmer's decision to grow a short-duration food crop or a long-duration tree crop. Cash availability also can affect a decision about how much to grow (a larger area can require more labour for land clearing, harvesting, or application of fertilizer). The selection of specific farm enterprises (crop or livestock) can affect cash flow by the timing and ease in which they can be sold. For example, small animals can be more easily converted into cash (and, therefore, contribute to the liquidity of a farm) than most crops. Liquidity is the capability of a farmer to produce cash and the cost of doing so.

Fixed capital items such as buildings and machinery are not included in Fig. 1 as a separate category or resources. To simplify the diagram, and because of the general lack of these items on the average farm in the Third World tropics, these items are assumed to be part of the farm household component. But it should be recognized that in some situations it would be inappropriate to include these items as farm components.

Figure 1 can be used as a guideline for drawing a diagram that represents the actual components, component linkages, and farm inputs and outputs. When such a qualitative framework has been developed, the next steps are to develop a quantitative description of the key farm system components and develop a quantitative framework that can be used to identify and evaluate potential technology within the key components.

Linking Templates to Form an Analytical Framework

After the key components of a farm system are described quantitatively, the next step is to integrate the component-level descriptions to form an analytical framework. Because the key components are selected on the basis of their interactions with the target research component, it is relatively easy to integrate component descriptions.

In the case of the five farm components described earlier, the outputs from the land component are inputs to the other components, the outputs for the crop and forage production systems are inputs to the feed storage system, and the outputs from the feed storage system are inputs to herd system. If the templates used to describe the components are designed correctly, the outputs from one component and the inputs to another should be in a common unit measured over a common time interval with a common frequency.

Figure 2 depicts a process that can be used to develop a farm-level or subsystem-level analytical framework. At the top of the figure are a set of resource templates and production system templates; at the bottom is an analytical framework formed by linking component-level templates. Since all component templates have at least one input that is an output of another component or one output that is an input to another component, the integrated framework is relatively easy to put together. This is assuming, of course, that the data has common units and are taken over common time intervals.

The usefulness of an analytical framework based on a set of integrated farm components can best be discussed by presenting a case study based on a real farm situation. The

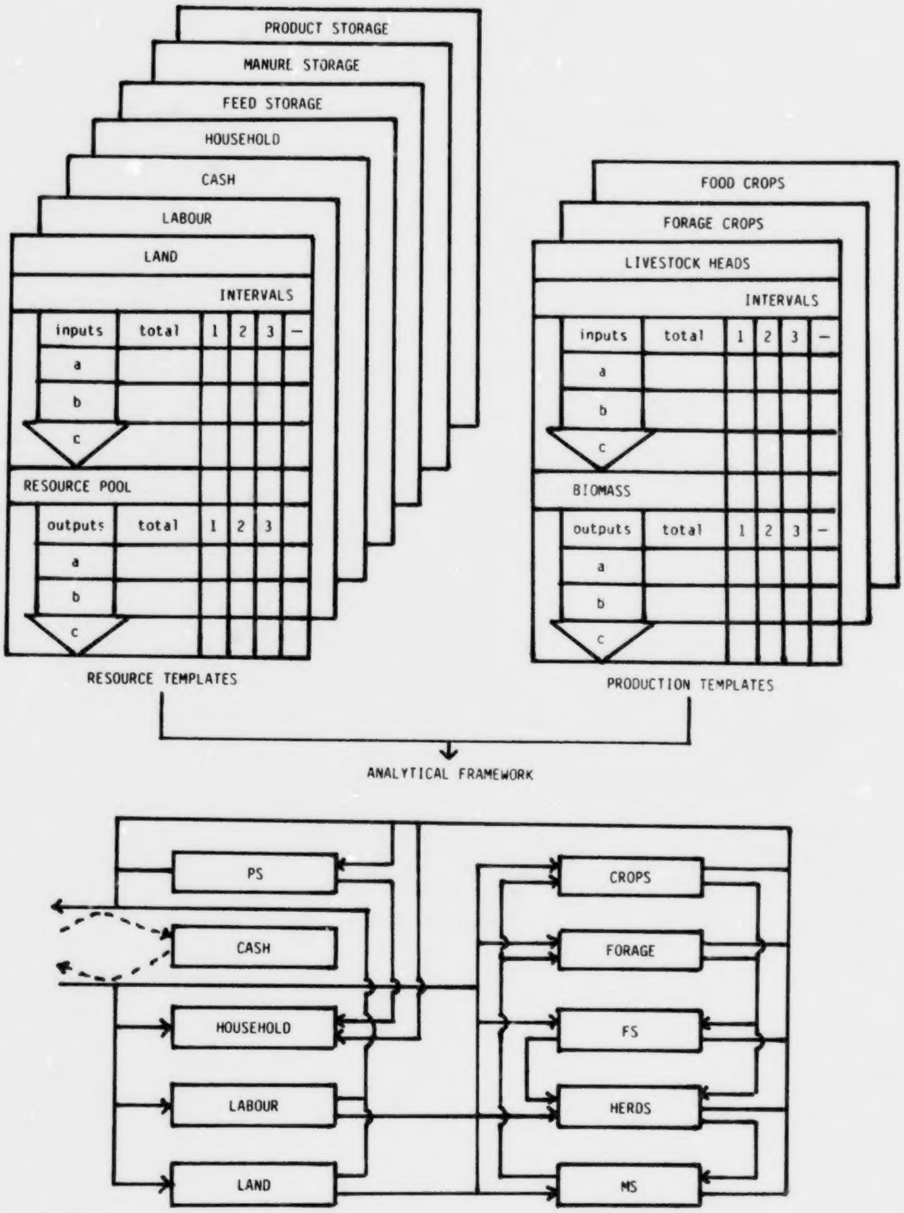
PRODUCT STORAGE
MANURE STORAGE
FEED STORAGE
HOUSEHOLD
CASH
LABOUR
LAND
INTERVALS
inputs
total
1
2
3
—
a
b
c
RESOURCE POOL
outputs
total
1
2
3
a
b
c
FOOD CROPS
FORAGE CROPS
LIVESTOCK HEADS
INTERVALS
inputs
total
1
2
3
—
a
b
c
BIOMASS
outputs
total
1
2
3
—
a
b
c
RESOURCE TEMPLATES
PRODUCTION TEMPLATES
ANALYTICAL FRAMEWORK
PS
CASH
HOUSEHOLD
LABOUR
LAND
CROPS
FORAGE
FS
HERDS
MS

Fig. 2. A process to develop an analytical framework by combining farm component data to form a network that links component inputs and outputs. PS, product storage; FS, feed storage; MS, manure storage.

following case study illustrates how an analytical framework formed by combining crop, forage, feed storage, and herd components can be used to select and evaluate both forage and livestock technology.

CASE STUDY

The Ministry of Agriculture and Livestock Development of Kenya is collaborating with several institutions from the United States in the implementation of a project that has the objective of evaluating the potential of dual-purpose (milk and meat) goat production systems on small mixed farms in western Kenya (Sands et al. 1982). The project started with a general characterization of predominant farming systems in the target area. After an initial survey, a study of 80 representative farms was conducted by monitoring each farm every 26 days for a 2-year period.

It was recognized early in the project that a key to the adoption of a dual-purpose goat production system was availability of feed. Biological research to improve livestock breeds, health, and management had to be complemented by research to identifying ways of improving feed availability. Moreover, this increase had to occur at the appropriate time and be of appropriate quality.

Figure 3 is a diagram of a farm system that is "typical" in western Kenya. The diagram includes many of the farm components, component linkages, and farm inputs and outputs identified in the generalized farm diagram in Fig. 1. The farm systems have cattle, sheep, and goat herds; double-cropped maize, maize and intercropped maize and bean rotations, and cassava crop production systems; and forage production areas along fence rows, in fallow areas, and off the farm. Crop and livestock production is linked by the use of crop residue as livestock feed and there is a limited use of manure as a crop fertilizer. Sales of crop and livestock products and family labour generate cash that is used to purchase both crop and livestock production inputs and food and household articles.

An analytical framework was developed by linking land, three crop-production systems, two forage production systems, feed storage, and three livestock herds (Hart et al. 1984). Figure 4 shows the network formed by these components. At the top of the figure is a diagram showing the flow of digestible energy through the network before any new technology has been

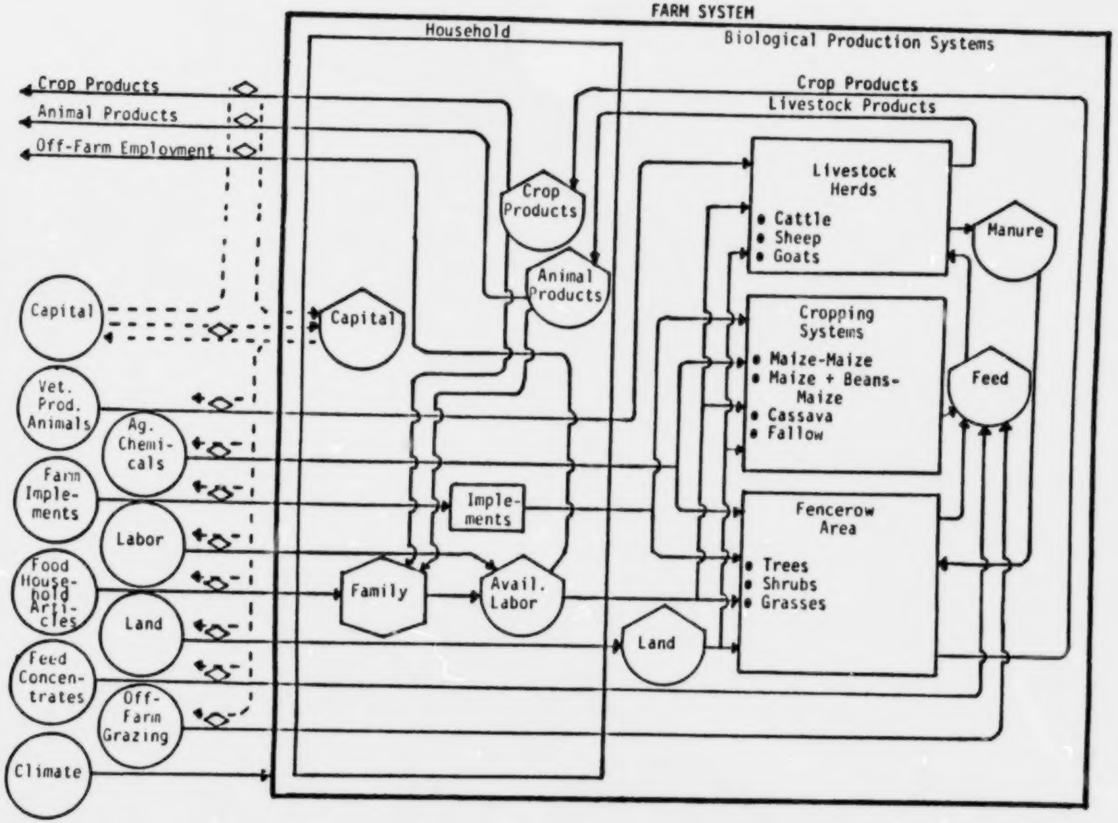
FARM SYSTEM
Household
Biological Production Systems
Crop Products
Animal Products
Off-Farm Employment
Crop Products
Livestock Products
Livestock Herds
• Cattle
• Sheep
• Goats
Manure
Crop Products
Animal Products
Capital
Cropping Systems
• Maize-Maize
• Maize + Beans-Maize
• Cassava
• Fallow
Feed
Capital
Vet. Prod. Animals
Ag. Chemi-cals
Farm Imple-ments
Imple-ments
Fencerow Area
• Trees
• Shrubs
• Grasses
Labor
Food House-hold Arti-cles
Family
Avail. Labor
Land
Land
Feed Concen-trates
Off-Farm Grazing
Climate

Fig. 3. A general farm system model (adapted from Hart et al. 1984) of a mixed farm in western Kenya showing the flow of materials, energy (solid lines) and money (dotted lines) from sources outside the farm (circles), among household and biological subsystem, to produce farm outputs. Resource pools that can be allocated to multiple processes are shown as "tank" symbols (symbols described in detail in Odum 1983).

introduced. At the bottom of Fig. 4 is the same network with new feed production technology and new livestock technology.

The data shown in Fig. 4 was summarized by using templates similar to that described in Fig. 2. The microcomputer-based templates were then combined to form a large spreadsheet that allows researchers to change the amount of land allocated to different crop and forage production systems, feed production per unit area, feed quality, and herd composition and herd structure. The spreadsheet does not calculate livestock production as a function of inputs (e.g., milk produced as a function of feed consumed), nor does it identify a land allocation recommendation that would minimize economic return, such as could be obtained from a simulation model or a linear model. The project research team, however, found the analytical framework to be useful both for designing forage production experiments and for evaluating the results of on-farm experiments.

USING AN ANALYTICAL FRAMEWORK FOR SOCIOECONOMIC ANALYSIS

The analytical framework described is a useful basis for socioeconomic analysis. The key question faced by farmers is how to allocate their land, labour, cash, and other household resources for their various farm enterprises (see Fig. 1). The templates offer an organized listing of the quantities of resources used (inputs) and products (outputs). Once these technical input-output relations have been modeled, socioeconomic values can be tagged to these inputs and outputs. Return to individual resources or the total resources of the farm are then calculated. Some aspects that are particularly related to the small ruminant production subsystem (or enterprise), however, should be taken into consideration. The socioeconomic aspects of resources allocation as it relates to small ruminant enterprises are discussed in the following.

Land

Cost-benefit analyses generally provide three types of economic criteria of profitability: returns to land, returns to labour, and returns to capital. Of these three criteria, returns to land is the one most commonly used by farming systems economists. It translates easily to yield data that is a main selection criteria for biological scientists.

In many instances, returns for unit land (e.g., 1 ha) is a useful standard, as good quality land (e.g., irrigated land) is

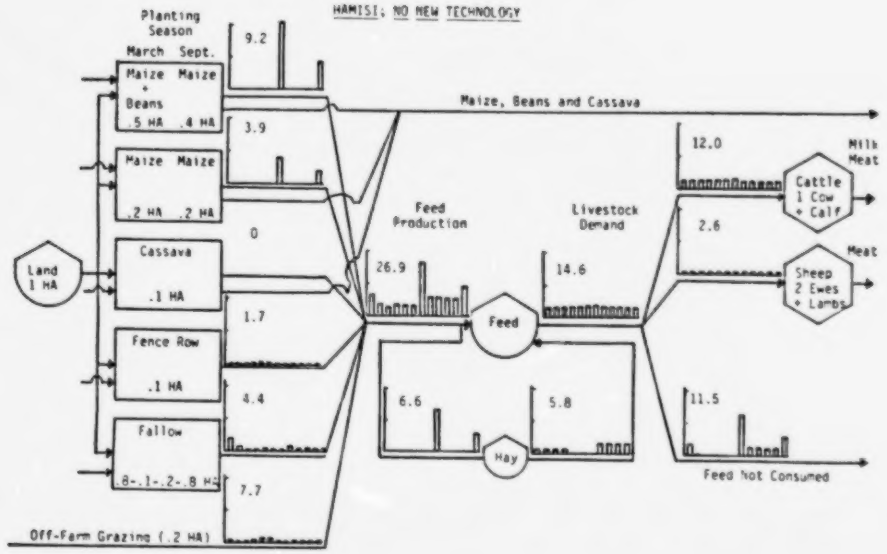
HAMISI; NO NEW TECHNOLOGY
Planting Season
March Sept.
Maize + Beans .5 HA
Maize .4 HA
Maize .2 HA
Maize .2 HA
Cassava .1 HA
Fence Row .1 HA
Fallow .8-.1-.2-.8 HA
Off-Farm Grazing (.2 HA)
Land 1 HA
9.2
3.9
0
1.7
4.4
7.7
Maize, Beans and Cassava
Feed Production
26.9
Feed
Livestock Demand
14.6
6.6
Hay
5.8
12.0
Milk
Meat
Cattle 1 Cow + Calf
2.6
Meat
Sheep 2 Ewes + Lambs
11.5
Feed Not Consumed
HAMISI; NEW FEED AND GOAT TECHNOLOGY
March Sept.
Maize + Beans + Pigeon Pea .5 HA
Maize .4 HA
Maize + Sudan Grass .2 HA
Maize .2 HA
Cassava .1 HA
Fence Row + Pigeon Pea .1 HA
Fallow .8-.1-.2-.8 HA
Off-Farm Grazing (.2 HA)
Land 1 HA
14.4
7.5
0
2.8
4.4
7.7
Maize, Beans and Cassava
Feed Production
36.8
Feed
Livestock Demand
24.7
8.2
Hay
7.9
12.0
Milk
Meat
Cattle 1 Cow + Calf
2.6
Meat
Sheep 2 Ewes + Lambs
10.1
Milk
Meat
Goats 4 Does + Kids
11.8
Feed Not Consumed

Fig. 4. Flow of feed from six feed resources to three livestock herds in a 1.0-ha farm system in Hamisi, western Kenya, with and without new feed and goat technology (adapted from Hart et al. 1984). Flow of digestible energy = 1000 Mcal/year; histograms show monthly distributions.

a scarce commodity. One special aspect of small ruminant production, however, is that it usually uses marginally productive land. Fragile soils often do not lend themselves to food crop cultivation and are better used as pastures. This type of land use has two important aspects: the land has low opportunity cost (the benefits the land would yield if used for the next best purpose) and the land is less in demand and, thus, less scarce.

The important implication is that return to land is often not a useful criteria for analyzing small ruminant production. As a matter of fact, landless farmers in West Java, Indonesia who have sheep or goats, derive up to 25% of their agricultural income from the small ruminant enterprise; obviously for them land does not seem to be a limiting factor.

Labour

Returns to labour is an important element in farmers' decisionmaking. A farmer's management can be analyzed by identifying the farm activities where a farmer allocates his or her own time (and that of his or her family). Especially in the case of confinement systems (cut and carry), labour is generally believed to be the most limiting resource. In analyzing labour use for small ruminant production, three aspects should be taken into consideration: labour measurement, quality of labour, and seasonality in labour requirements.

There are two basically different approaches to measuring labour: the normative approach and the descriptive approach. Normative labour data are found under experimental (controlled) conditions. From such experiments, labour norms can be derived. These are the labour requirements given a certain level of technology, other inputs factors, market conditions, and other environmental factors. By recognizing that some farmers will seldom reach these norms, it can be generally assumed that normative labour requirements are different from labour use by the "average" farmers. The descriptive approach, however, focuses on actual labour use. Only by assuming that all farmers allocate their labour effectively under very similar conditions can these data be used as labour norms.

Another aspect is the quality of labour. There is a large difference between the type of labour required for one hour of land cultivation, and that for 1 hour of sheep herding. In a recent study of small ruminant integration into rubber estates, Amir and Knipscheer (1987) made a distinction between two types of labour. The hard chores such as plowing fields, weeding, transplanting rice, etc., are defined as "hard labour," whereas chores that can be performed in leisure time or do not require much physical input are defined as "leisure labour." These two categories are incorporated in their model in such a way that the labour in one category can be transferred to the other. For example, it is assumed that a farmer generally will work 5-6 h of "hard" labour and 2-3 h of "leisure" work. But in peak demand periods, he or she can sacrifice "leisure" time for "hard" time. Obviously, such time will be less productive, because a farmer will have already worked 5-6 h on hard chores. It is assumed, therefore, that, after hard work, 1 h of leisure working would be equivalent to only 0.33 h of hard time. If the farmer would work fewer hours of "hard," however, he or she would be able to extend the leisurely work or make that time more productive. It is assumed, therefore, that the farmer has the option to gain 2 h of leisure time for each hour of "hard time."

The distinction between two types of labour requirements and input is based on the notion that various households and farming tasks require different levels of labour quality. This is especially relevant for small ruminant keeping. Livestock management activities consist of herding or grass cutting, grass transport, and feeding. These are all light activities often performed by children, women, or older members of the family. This type of labour has a lower opportunity cost, just as lower quality land has a lower opportunity cost than high-quality land.

Seasonality in labour requirements in crop cultivation contrasts sharply with the lack of fluctuation in labour requirements for small ruminants. Mulyadi et al. (1983) found relative small fluctuations in labour utilization for sheep and goats in West Java between the dry and wet seasons. Livestock, in general, therefore, represent a rather stable employment opportunity in agriculture.

Cash

Farmers universally identify lack of cash as their most limiting factor; lack of cash is their main constraint. Returns to cash is, therefore, an important decision criteria. Partial budgeting of new technologies will yield benefits/cost ratios. This ratio can be easily adapted to a benefit/cash cost ratio. As small ruminants tend to be a secondary farm enterprise, benefit/cash costs ratio between alternative technologies for a given enterprise, as well as between alternative enterprises should be compared. For example, drenching might have a high benefit/cost ratio compared with no drenching. Nevertheless, farmers might prefer to spend their scarce cash on fertilizer for paddy rice, rather than on livestock drugs.

Earlier, the role of small ruminants for farm liquidity was discussed. Indeed, the small ruminant flock represents a quantity of cash, readily available. Flock yields, therefore, can be interpreted as cash yields, which again implies returns to cash resources. Socioeconomic scientists, therefore, can borrow flock productivity parameters from their biological colleagues such as doe/ewe reproduction indices and doe/ewe productivity indices (Knipscheer et al. 1984).

Household

Other household resources include possible barn buildings and fences, as well as the farmer's experience. As a matter of fact, the farmer's knowledge and understanding of animals is generally ackowledged as an essential determinant of the success or failure of livestock production. This "knowledge" accumulated in a household is sometimes referred to as the "human capital" of a household. Human capital is not concentrated in one person, but spread over all family members. For example, because of the proximity to the house and their attention to health care, wives might detect unusual behaviour of an animal because of disease earlier and easier than their husbands.

The household is also the focus of interaction between farms. Studies of households include analyses of relationships between families, between farmers and village institutions, and other phenomena in the household environment. For example, small ruminants are sometimes kept as pets, sometimes for ceremonial use, and other times for status purposes. Human capital is built by experience and communications. Technology transfer is often conceptualized as the communication of production constraints by extension agents to researchers, and the communication of technical recommendations from researchers to extension agents. The analytical framework, therefore, is also useful in stimulating interactions between technology-generating scientists and social scientists focusing on technology transfer.

CONCLUSION

An analytical framework can perform a vital function of enhancing understanding between researchers of different disciplines, especially between social and biological scientists, and improving communication between research and extension. As extension and research collaborate in the first phases of agricultural systems research, they can together develop the farm-level qualitative framework (Fig. 1) that will guide the development of a quantitative framework. When research results are promising and extension participates in evaluation of the new technology, the analytical framework can be used to identify the characteristics of the farms where the new technology will have a high probability of being adopted and of having a development impact.

Although the development of an analytical framework is an important activity for a production systems research team, it should be noted that a framework without alternative technology is of no value. An analytical framework is only a tool, not an end in itself. There is no doubt, however, that an analytical framework can be an important tool. In many projects, it is appropriate to clearly distinguish between activities to develop an analytical framework and activities to identify and test technology. It must be remembered, however, that the objective of both types of activities are to contribute to an integrated development-oriented research and development process. The approach is partially relevant for small ruminant production, where the opportunity costs of land and labour, and special capital liquidity cosiderations, all relate to the other components of the farm.

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SMALL RUMINANT PRODUCTION SYSTEMS

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Abstract *Small ruminant production systems in South and Southeast Asia and the South Pacific are primarily traditional systems. These can be classified into three main systems: extensive systems; systems combining arable cropping to include roadside, communal, and arable grazing systems, tethering, and cut and carry systems; and systems integrated with tree cropping. Of these, the systems integrated with tree cropping have not been exploited and, therefore, merit the highest priority. Within the production systems there exist 53.4 and 22.9% of the total population of goats and sheep in Asia, respectively, that have annual growth rates of 1-2%. The per caput goat meat supply is decreasing, whereas that of mutton is increasing. The value of ownership of these species is reflected in several advantages and include income, food, security, employment, fertilizer, social values, recreation, and by-product feed utilization. The traditional nature of these systems stems from secondary position of goats and sheep in mixed small farm systems, lack of incentives, and new innovations that do not stimulate production. The major constraints to the production systems are inefficient use of the goat and sheep genetic resources, management, diseases and health, and inadequate marketing outlets. This trend, if left uncorrected, is likely to continue. Potential improvements to the production systems are, therefore, urgently necessary, including the need for appropriate methodology that can make a significant and rapid impact on production. Expanding production for both species calls for major shifts in resource use and especially new innovations that are demonstrably more superior and consistently profitable.*

Ruminant production throughout South and Southeast Asia is at present a priority in livestock development programs. There are three principal reasons. First, relative to the contribution by crops, ruminants have failed to keep pace with the increasing demand by humans, of food of animal origin. Second, compared with the larger, very intensive and more successful nonruminant pig and poultry industries found in urban fringe areas, ruminants, with few exceptions, have not demonstrated a parallel success. Third, there is the important point that among ruminants, goats and sheep are traditionally owned and serve a wide variety of functions in the preponderance of small farm systems that are characteristic of Asian agriculture involving several millions of small farmers, landless labourers, and peasants in essentially rural areas (Devendra 1983). Because of these reasons, it is appropriate to examine the nature of the production systems in the context of current and future contribution.

Small ruminant production systems form a component of farming systems (Duckham and Masefield 1970; Ruthenberg 1976; Spalding 1979). Although agroecological conditions determine the types of crops and livestock systems suitable to any one location, the prevailing ruminant production systems have evolved in response to the total availability of land, the type of crop production practiced, the frequency of cropping, the area of uncultivated wasteland, and the density of animal populations.

At present, within the developing countries, small ruminant production systems are primarily traditional. Part of the reason for this is because goats and sheep play a secondary role to crop production, have not received adequate research and development support, and are generally of low priority in animal production programs. A recent report by the World Bank (1983) concluded from an analysis of 80 research or development projects on a regional basis that there was a lack of support within the developing countries and international donor and lending agencies. Equally important, there have been few changes and improvements to encourage the creation of more efficient productive systems. In turn, this has resulted in little if any major shift toward the development of commercial production systems that are consistent with increased productivity.

The fact remains, however, that small ruminants play an important and contributory role to the stability of complex small farm systems such as those found in Asia (Devendra 1976, 1983). Attempts to improve the prevailing systems must necessitate a better understanding of the components of the production systems, the present limitations, potentially feasible improvements, and the opportunities to develop more productive systems. This paper examines and discusses these aspects.

GOAT AND SHEEP POPULATIONS

Goats and sheep in South and Southeast Asia account for 53.4 and 22.9% of the total population of these species in Asia, respectively (Table 1). India has the largest goat and sheep population, accounting for 59 and 57%, respectively, of these species in South and Southeast Asia. Indonesia accounts for about 6% of both the goat and sheep populations of the region. The ratio of sheep to goats is 1:1.8. The rates of growth of the individual species over the last 10 years from 1974-76 to 1984 were 2.1 and 1.5% respectively, indicating that the goat population is growing faster than the sheep population in South and Southeast Asia.

Goats were responsible for 54.1, 53.8, and 57.6% of the total production of meat, milk, and skin in Asia, respectively. Also, sheep were responsible for 19.8, 1.4, 20.8, and 19.7% of the total mutton, milk, skin, and wool production, respectively, in Asia (Table 2).

Table 1. Goat and sheep resources of South and Southeast Asia.

Species	Population		Annual growth rate (%)	
	Total (x 10^6)	% of Asian population[a]	1974-76 to 1984	% of total grazing ruminants in Asia
Goats	136.2	53.4	2.1	12.6
Sheep	73.0	22.9	1.5	6.8

Source: FAO (1984).

[a] Goats, 255.2 x 10^6; sheep, 322.9 x 10^6.

Table 2. The relative contribution of goats and sheep in South and Southeast Asia.

	Goats		Sheep	
Product	Production (t x 10^3)	% of total Asian production	Production (t x 10^3)	% of total Asian production
Goat meat	661	54.1	-	-
Mutton	-	-	353	19.8
Goat milk	1907	53.8	-	-
Sheep milk	-	-	52	1.4
Goat skins[a]	135891	57.6	-	-
Sheep skins[a]	-	-	73983	20.8
Wool (greasy)	-	-	89466	19.7

Source: FAO (1984).
[a] Actual production (fresh).

GOAT AND SHEEP GENETIC RESOURCES

Over the three periods 1961-1965, 1974, and 1984, the percentage proportion of carcass meat accounted for by goat meat was 3.9%; for mutton in the last decade, 5.6%. The per caput (per adult person) goat meat supply suggests that this is generally static (0.40-0.47 kg/year), but for mutton it is increasing (0.56-0.64 kg/year).

Table 3 identifies and summarizes the names of the more important goat and sheep breeds in South and Southeast Asia. Although 12 "improver" breeds are identified, this list is by no means complete. Each of these breeds has a specialty and the approximate adult live weight of the doe is also given. A number of these breeds, such as the Jamnapari, Beetal, and Marwari in India, and Damani, Dera Din Panah, and Kamori in Pakistan, are dairy breeds. There has been very little or no selection, however, for improved milk yields with all these breeds. Thus, their potential milk-yielding capacity is not very certain. The Fijian and Sirohi are outstanding meat breeds and respond to good live weight gains in efficient feeding systems. The Black Bengal and Malabar breeds from

Table 3. Important goat and sheep breeds in South and Southeast Asia.

Breed	Country	Speciality	Approximate adult live weight of female (kg)
		Goats	
Barbari	India	Milk, meat, prolificacy	27-35
Beetal	India	Milk	40-45
Black Bengal	India	Prolificacy	9-15
Damani	Pakistan	Milk	21-25
Dera Din Panah	Pakistan	Milk	40-42
Fijian	Fiji	Meat	30-35
Jamnapari	India	Milk	45-60
Kamori	Pakistan	Milk	50-55
Katjang	Malaysia, Indonesia	Prolificacy	22-23
Malabar	India	Prolificacy	40
Marwari	India	Milk	25-27
Sirohi	India	Meat	50-53
		Sheep	
Baluchi	Pakistan	Mutton	35-40
Chokha	India	Coarse wool	23-25
Indigenous	Malaysia	Coarse wool	22-24
Javanese thin tailed	Indonesia	Prolificacy, mutton	25-28
Priangan	Indonesia	Prolificacy, mutton	27-30
East Java fat tailed	Indonesia	Prolificacy, mutton	30-35
Jaffna	Sri Lanka	Hair	18
Lohi	India	Mutton, prolificacy	22-28
Mandya	India	Mutton	28-30
Nellore	India	Mutton	38-42

India and the Katjang from Malaysia are prolific breeds, but, yet again, there has been no selection for this trait. The Barbari is a dual- or triple-purpose breed that has considerable potential for use in development programs.

Of the 10 sheep breeds identified in Table 3, the Nellore and Mandya from India and the Baluchi from Pakistan are good mutton breeds. With the exception of the Lohi breed in India, Indonesia has at least three outstanding prolific breeds in the Javanese thin-tailed, Priangan, and East Java fat-tailed goats. Although high variability in litter size has been noted, there are indications of a high repeatability of ovulation rate in the Boorola type (Bradford et al. 1984). These breeds are particularly valuable for improvement programs and in the multiplication of numbers. Two useful breeds for coarse wool production are the Chokla from India and the indigenous sheep in Malaysia (Devendra 1975). The sheep and goat breeds of Indian have recently been described by Acharya (1982) and of Pakistan by Hasnain (1985). Although many of the breeds have been described, their potential productivity remains largely unknown.

ECONOMIC IMPORTANCE OF GOATS AND SHEEP

An indication of the economic importance of rearing goats and sheep is found in detailed studies on the subject recently reported in Indonesia (Knipscheer et al. 1983). This study indicated that the involvement of rural households in West Java in raising small ruminants is large, that one out of every five farmers keeps sheep or goats, and participation by farmers can be as high as 30%. The estimated share of small ruminant income of the total income is indicated in Table 4. The contribution of the goat and sheep enterprise in the total farming income is substantial and was about 14, 17, and 26% for the three categories of lowland, upland, and rubber plantation situations, respectively. The report also indicated that the income share of the small ruminant enterprise increased as the farmer's resource base, especially land, decreased.

SIGNIFICANCE OF OWNERSHIP

Goats and sheep are raised with several objectives in mind. They serve the material, cultural, and recreational needs of the farmers. Their ownership has the following advantages:

- Income: important means of earning supplementary income.
- Food: provide animal proteins (milk and meat) that are important for the nutritional well-being of peasants.

Table 4. Estimated share of small ruminant income of total income in West Java, 1980.

Location	No. of farms surveyed	Annual income per farm (IDR)[a]	Small ruminant income	
			Total (IDR)[a]	% of annual income
Cerebon (lowland)	79	222000	37593	17.1
Ciburuy (rubber plantations)	66	180000	46671	25.9
Garut (upland)	135	300000	41466	13.8

Source: Knipscheer et al. (1983).

[a] In October 1986, 1625 Indonesian rupiah (IDR) = 1 United States dollar (USD).

- Security: sources of investment, security, and stability.
- Employment: creation of employment including effective utilization of unpaid family labour.
- Fertilizer: contribution to farm fertility by the return of dung and urine.
- By-product utilization: they enable economic utilization of nonmarketable crop residues.
- Social values: the ownership of animals has been shown to increase cohesiveness in village activities.
- Recreation: socioeconomic impact of animal ownership also includes a recreational contribution to small farmers.

The small size of the ruminants is a distinct advantage in the complexity of small-scale farm systems. There are definite economic, managerial, and biological advantages.

- Economic: low individual values mean a small initial investment and correspondingly small risk of loss by individual deaths. This makes goats and sheep an attractive proposition for household use and subsistence farming, especially for poor families.
- Managerial: goats and sheep can conveniently be cared for by women and children, occupy little housing space, and supply both meat and milk in quantities suitable for immediate family consumption, which is important in view of the difficulties of storage in the tropics.
- Biological: one or two goats or sheep can be kept when nutrition is inadequate for even one cow.

PRODUCTION SYSTEMS

Small ruminant production systems in South and Southeast Asia have endured in relation to the overall pattern of crop production and farming systems. They are especially dependent on the agroecological environment and, as ruminants, must always depend on vegetable or crops for their feed base. The reference to the agroecological environment is important because in the more arid regions, the sparse vegetation provides a weak feed resource base. For this reason, the small ruminant production systems are primarily nomadic and transhumant systems.

By comparison, in the humid tropics, which is characteristic of South India and most parts of Southeast Asia, feed resources are more abundant and, hence, sedentary systems that can also be intensive systems become possible. This also enables the more important crop and livestock systems to develop.

Table 5 brings together types and characteristics of predominant farm systems involving ruminants, including goats and sheep, in Asia. The table identifies the cropping pattern (wheat, rice, maize, or a combination of these; and cocunuts, oil palm, and rubber), type of ruminants reared, production objective, and gives approximate sizes of goat and sheep flocks. The latter are variable and partly dependent on the

Table 5. Types and characteristics of crop farm systems involving small ruminants in Asia.

Cropping pattern	Ruminants	Small ruminant production objectives	Average size of goat and sheep flocks	Current importance[a]
Rice	Buffalo, cattle	Goat meat, mutton	1-5	Low
Mixed rice-maize[b]	Cattle, buffalo, goat, sheep	Goat meat, mutton	1-5	Low
Mixed rice-wheat	Cattle, buffalo, goat, sheep	Goat meat, mutton, milk	10-30	Medium-low
Mixed rice	Buffalo, cattle, goat, sheep	Goat meat, mutton	1-5	Low
Wheat	Cattle, buffalo	Goat meat, mutton, milk	10-30	Medium-low
Wheat-rice	Cattle, buffalo	Goat meat, mutton	10-30	Medium-low
Coconuts	Goat, sheep	Goat meat, mutton	10-40	Medium-low
Oil palm	Buffalo, goat, sheep	Goat meat, mutton	8-30	Medium-low
Rubber	Cattle, goat, sheep	Goat meat, mutton	8-30	Medium-low

[a] Based on average ownership by small farmers, landless labourers, and peasants.
[b] Mixed crops refer to root crops, oil seeds, cash crops, vegetables, and fodders.

nature and extent of the crop residues produced. When mixed cropping is involved, the table also provides the types of crop grown. The last column of Table 5 gives an indication of the current importance of goats and sheep in each of the main systems, based on average ownership by small farms, landless labourers, and peasants. Asian livestock production and management systems have recently been described (Camoens 1985).

Small ruminant production systems can be classified as follows: extensive systems; systems combining arable cropping to include roadside, communal, and arable grazing systems, tethering, and cut and carry feeding; and systems integrated with tree cropping.

Extensive Systems

This system is by far the most common for all ruminants throughout the Asian region. It is characterized by small ruminants, usually owned by small farmers, grazing on all available grazing areas, largely uncultivated, including marginal land, for varying periods during the day. The length of the grazing period is dictated primarily by the type of ruminant and the objectives of production, i.e., meat or milk.

The system has certain very definite features. Rearing ruminants is secondary to crop production, consistent with the pattern of agriculture. Usually, more animals tend to be carried than in the intensive system, probably because these animals have access to plenty of grazing land. Buffalo and cattle tend to be grazed separately, but where goats and sheep are reared, these small ruminants are grazed together, probably because goats tend to lead the herd. Additionally, the small ruminants tend to be herded over longer distances compared to buffalo and cattle, which are relatively more sedentary.

The flock sizes are larger (1-15 herd), and animals, often goats and sheep belonging to several owners, are run together and brought back in the evening. Stocking rates are usually in the range of 1-4 head/ha. Very extensive systems are rare, as with other parts of the humid tropics, presumably because of the availability of more forage and crop residues.

In the extensive system, a low level of unpaid family income represents the main input. By implication, the use of this unpaid family labour, usually women and children, represents an aspect of effective labour use whereby both cropping and rearing of ruminants represent important components of farm income. Except for the use of this low labour input, the system is principally one of low resource use, and a generally low level of productivity emerges from substandard nutritional management where very little or no concentrates, salt, or mineral licks are provided, except in the case of dairy cows.

Systems Combining Arable Cropping

Ruminant production systems combining arable cropping have evolved in situations where crop production is important to contribute to the stability of the system. Animals do not compete for the same land and play a supplementary role to arable cropping. Three types of systems are common: roadside, communal, and stubble grazing; tethering; and cut and carry feeding.

The three systems are not mutually exclusive. Grazing on roadsides and on communal (waste) land may be practiced by landless stock owners as well as others when their privately owned lands are under arable crop cultivation. Grazing in rice fields is restricted to periods immediately after harvest when the feeds available consist of the aftermath of the rice crop (i.e., rice stubble and some regrowth from the stubble), any weeds that grow in the paddies, the grasses that are found on paddy bunds, and browse from shrubs and trees that grow in it. Where multiple cropping is practiced, the crop aftermath may be burnt after the harvest and stubble grazing may be severely restricted or nonexistent.

Tethering is adopted when there is a need to prevent animals wandering into areas being cropped and to ensure that they graze down the available feed in a given area before they are moved. This type of confinement feeding is most popular in Southeast Asia because multiple cropping is widespread in this region. The animals may be tethered on waste grazing areas close to the farm or on rice fields after harvest to regulate stubble grazing or close to stacks of rice straw to allow self-feeding.

In the cut and carry system, a large proportion of the feed is usually brought in from outside the holding area because of the small size of holdings in relation to the number of animals kept. The system is subject to the vagaries of seasonal abundance and shortage of forage that characterize it. Because the livestock is housed most of the time, their growing dependence on high-priced concentrate feeds during lean periods increases.

The system together has had limited success because of the value of arable land for food production. This also presents a constraint to forage production for animals. The emphasis on crop production, however, makes large quantities of crop residues available, which are valuable as feeds, especially to ruminants.

The cut and carry or stall-feeding system requires high labour and capital investment. It is a system that favours situations where there is no land or, more particularly, the availability of abundant supplies of crop residues and agro-industrial by-products. Probably because of the higher capital investment, it has not been adequately used as a system. In Fiji, it has been reported that goats fed sugarcane crops, stovers, straws, coconut cake, rice bran, and molasses reached live weight of 23-25 kg in about 22 weeks with a daily live weight gain of 154 g, compared with 83 g in the extensive system (Hussain et al. 1983). Likewise in India, Sehgal and Punj (1983) have demonstrated the value of feeding 80 g NaOH/kg with wheat straw, which gave maximum growth rates in growing kids.

Where land is available for intensive pasture production, however, it is feasible to also produce meat or milk from small ruminants. Only limited work has been done in the Asian and Pacific region in this context, and to compare meat production from goats vs cattle, studies have been completed to investigate their response and grazing behaviour to cultivated *Setaria setivalva* pasture fertilized with 150 kg N, 40 kg P, and 40 kg K/ha per year applied in three equal amounts. The average yield of dry matter (DM) was about 5-6 t/ha. Four stocking rates were used: 20, 40, 60, and 80 goats/ha in a randomized block design, replicated three times, involving Katjang crossbred kids with an initial live weight of about 10-12 kg. At the end of 4 months, the highest stocking rate rendered the paddock bare and this treatment had to be withdrawn.

The effect on daily live weight gain was dramatic (Table 6). Noticeable results occurred about 3 months after the experiment started, and the highest stocking rate only gave a daily live weight gain of 9.2 g/day per animal. Daily live weight gain was significantly correlated to body length ($r = 0.209$, $P<0.01$), height at withers ($r = 0.232$, $P<0.01$), and heart girth ($r = 0.306$, $P<0.01$). The results suggest that the optimum stocking rate for *Setaria* pastures is about 40 goats/ha.

Table 6. Effects of stocking rate on the performance of goats grazing *Setaria sphacelata* var. *splendida* pastures.

Parameter	Goats/ha			
	20	40	60	80
Mean live weight gain per animal (g/day)	43.2	41.2	29.0	9.2
Body length (cm)	103.3	102.5	99.4	99.3
Height at withers (cm)	53.2	53.2	52.0	51.1
Heart girth (cm)	59.1	59.5	57.7	56.4
Grazing time (min)	416.4	434.0	454.6	460.7
Resting time (min)	82.0	79.5	51.0	54.1
Distance walked (m)	852.1	664.4	813.3	801.3

Systems Integrated with Tree Cropping

This system can also be described under the intensive arable system, but it merits separate treatment, especially in view of the area under tree crops (coconuts, oil palm, and rubber) in South and Southeast Asia. More particularly, this is also justified by the fact that the system has considerable potential in increasing production from ruminants (Devendra 1985a) in view of the expanding hectarage under these tree crops.

This system is especially common in the humid and subhumid regions where this is intensive crop production. Although the system is not new, integration with these tree crops to ensure more complete utilization of the land has not been given adequate attention. The advantages of the system are

- Increased fertility of the land via the return of dung urine,

- Control of waste herbage growth,
- Reduced use of weedicides,
- Reduced fertilizer wastage,
- Easier management of the crop, and
- Distinct possibilities of increases in crop yields, consistent with greater economic including sale of animals and their products.

An additional advantage inherent in the system is the presence of abundant shade offered by the trees. This creates an environment that reduces heat stress on the grazing animals.

Given these advantages, and considering the large area under such tree crop as coconuts, oil palm, and rubber in some countries in Southeast Asia and the Pacific islands, the potential carrying capacity and offtakes of meat (goat meat or mutton or both) from the land is, therefore, enormous. Many of the Pacific island territories, notably Papua New Guinea, New Hebrides, Fiji, the Soloman Islands, and Western Samoa, have large land areas under coconuts, implying that there is much potential for integrating goats or sheep into them. Reynolds (1979) has reported the yields for various cultivated grasses and estimated the stocking rates for cattle. On the basis of 3% of body weight (20 kg) and assuming complete utilization of the available dry matter produced, the very high, high, medium, and low levels of production can support 64-73, 45-64, 34-45, and 34 goats or sheep/ha, respectively, which, in terms of biomass production, must rate very competitively with cattle production.

The potential for this kind of activity is reflected in an estimated area of 20.3 x 10^6 ha under tree crops in South and Southeast Asia (FAO 1984). In Malaysia, for example, the combined total hectarage under rubber and oil palm is about 4.3 x 10^6 ha. Even if only half of this crop area is utilized by animals, and assuming a carrying capacity of 3 animals/ha, the total number of animal equivalents is 5.2 x 10^6, which is substantial. A specific example of the economic benefits of integrating goats with oil palm concerns the case history of an oil palm estate that allocated a portion of the grazing land within the estate to the workers for grazing their animals. For the first 2 years (1980 and 1981), only cattle were owned and grazed; in 1982 and 1983, however, goats were also introduced in addition to cattle. This was done in view of their economic importance and capacity to supply both meat and milk in the estate.

The comparison of the grazed and nongrazed area involving both young and mature trees is valid in that it involved the same area of 71-135 ha, and, more particularly, the fact that both areas were of the same soil type. The total cattle and goat populations were both about 80 and 220 animals, respectively. The differences in yield over the 4 years in favour of the effect of grazing cattle and goats was 2.15-5.16 t fresh fruit bunches per hectare per year with a mean value of 3.51 t of fresh fruit bunches per hectare per year (Table 7). When translated into the total hectarage grazed and sale value per tonne of fresh fruit yield, the economic advantage is substantial. The result in economic terms is similar to the findings in West Java of integrating goats and sheep with rubber (see Table 4). The presence of legumes is of definite advantage, and it has been calculated that the amount of N utilized by the animal and also excreted in the feces and urine increases with the presence of the legume cover (Table 8).

The value of small ruminants is also significant in the wider context of agroforestry systems. The complementary advantages are forage production, supply of fuelwood, improvement of soil fertility and permanent soil cover, and economic land use.

FUTURE TRENDS IN PRODUCTION SYSTEMS

With the prevailing patterns of animal production, and the resources currently being used to support them, ruminant production systems are unlikely to change (Mahadevan and Devendra 1985). It is the view of these authors that major shifts in resources use would be difficult unless returns from the new proposed systems are demonstrably superior. Changes must, therefore, be introduced gradually and must ensure income stability and low risk. The principal aim should be to make maximum use of the basic feed resources available, which is essentially crop residues or low-quality roughages or both. In addition, delivery systems should be developed for the essential supplementary feeds (leguminous forages, agroindustrial by-products, or other feed concentrates).

Table 7. Effect of mixed cattle and goat grazing on the yield of fresh fruits in an oil palm cultivation in Malaysia.

Year	Yield of fresh fruit bunches (t/ha) Annual grazed area	Annual nongrazed area	Difference
1980	30.55 (cattle)	25.61	4.94
1981	17.69 (cattle)	15.87	1.82
1982	25.12 (cattle and goats)	22.97	2.15
1983	23.45 (cattle and goats)	18.29	5.16
Mean	24.20	20.69	3.51

Source: Devendra (1985a).

CONSTRAINTS TO PRODUCTION SYSTEMS

There are several critical constraints to the prevailing small ruminant production systems. It is essential to discuss these briefly and to keep them in perspective. It is important to stress that although individual constraints are identified, almost all of them are interrelated and, thus, have a variable effect on the production systems. Of these, the ecological constraints are largely uncontrollable, but their effects on the environment, and especially on the biological components such as animals and feeds, are significant. It is, therefore, more pertinent to consider the latter aspects. Sometimes, one constraint can dominate the presence of others. Feeding and nutrition, for example, can override the influence of reproductive efficiency and disease status of goats and sheep. The effects of disease status are less when nutrition is adequate.

Goat and Sheep Resources

There are a number of valuable indigenous goat and sheep resources widely adapted to the climatic extremes found in Asia. The adaptational characteristics are unique to the environment within which they perform a host of very valuable functions. Unfortunately, however, although considerable

Table 8. Utilization of three systems of ground vegetation by indigenous sheep under rubber in Malaysia.

Vegetation[a]	Dry matter (kg/ha)	Crude protein %	Crude protein kg/ha	N content (kg/ha)	N retained[b] (kg/ha)	N utilized (kg/ha)
NC	500	11.4	57	9.1	0.5	8.6
NC and legumes	1400	15.0	210	33.6	1.6	32.0
Pure legumes	2600	24.4	619	99.0	4.9	64.4

Source: Chee and Devendra (1981).

[a] NC, natural cover.

[b] A 70% digestibility of crude protein and a 7% retention of nitrogen by the grazing animal is assumed.

advances have been made to identify and describe the majority of these breeds (Acharya 1982; Devendra and Burns 1983; Hasnain 1985), their potential productive capacity has not been adequately investigated. Thus, in many instances, although the adaptational and functional values are apparent, their genetic potential remains largely unknown.

A major reason for this situation is the limitation on productivity imposed by the other constraints, notably feeding and nutrition, management, diseases, and health. Additionally, there are inadequate development policies and support services, the improvement of which can also enhance increased productivity.

Feed Resources

The overriding constraint in the production system is feed (Devendra 1986). There are three aspects to the problem. First, there is the issue of increasing the efficiency with which the available feeds are utilized. These include forages, crop residues, agroindustrial by-products, and nonconventional feeds. It is suggested that prevailing feeding systems and the manner in which the feeds are used are inefficient, with the result that the productivity from both species is also low. Substantial improvements to feeding systems are, therefore, necessary in the quest to maximize productivity from small ruminants.

The second continuing problem is the inability to make maximum use of the total feed resources. Nonconventional feeds, which include several types of tree leaves, for example, are presently underutilized, despite the availability annually, of some 194 x 10^6 t in Asia and the Pacific (Devendra 1985b). It is significant to note that, of this total, about 93% of the feeds are suitable for feeding to ruminants.

The third aspect of this problem relates to inadequate supplies of feed such as those in Pakistan, India, and Indonesia, which severely curtail high performance. The objective here is to increase the feed supply on a year-round basis.

Management

Poor husbandry practices drastically reduce the response from goats and sheep and, therefore, reduce their productivity. Conversely, the effects of improved feeding and management on performance are spectacular and are seen in the results reported in goats in Malaysia (Devendra 1979) and goats in India (Sachdeva et al. 1973; Parthasarathy et al. 1983). In Fiji, improved husbandry, feeding, disease control, and breeding has been shown to increase the annual rate of reproduction from 120 to 180%, and well-fed does to produce their first kid within 12-13 months of age (Hussain et al. 1983). This is, therefore, an area that merits very much more attention than in the past in all types of integrated systems involving crops and animals as indicated in Table 5.

Diseases and Health

The wastage caused by disease represents a source of major economic loss in goats and sheep. These losses can be broken down into three categories:

- Lowered resistance, caused by undernutrition and malnutrition resulting in deaths by various diseases;

- Parasitism mainly caused by roundworm infestation is a major cause of loss throughout the tropics and is associated with poor nutrition and reduced resistance; and

- Transmissable diseases, such as coccidiosis and caseous lymphadenitis and pneumonia, are serious, cause high mortality, and necessitate disease monitoring, appropriate prophylactic measures, or vaccination.

Goats appear to be more susceptible to gastrointestinal parasitism than sheep. In Bangladesh, for example, 176 of 214 kids (82.2%) born died within 6 months; respiratory disorders, gastrointestinal parasitism, and contagious ecthyma were the main causes. In adults, 47.8% mortality was recorded for gastrointestinal parasitism and respiratory disorders (Abdur Rahman et al. 1976). Also, in Sri Lanka, kid mortality from 2340 pregnancies was reported to be 28% (Ranatunga 1971).

Products from Goats and Sheep

The inefficiencies that are apparent in the production systems result in the relatively low contribution from the species especially in terms of meat, fibre, and skins. This situation is consistent with the view that production of these commodities remains primarily a traditional enterprise. There is very limited commericial production of these same products, especially for markets such as in the Near East where there is a growing and large market preference for goat meat and mutton.

Clearly, improvements are necessary to the production process and include inter alia better use of the production resources (land, labour, and capital), incentives, credits, transportation, and market outlets. In this context, there is a need for cost-effective, commercial small ruminant production enterprises that can demonstrate the application of known technology and potentially profitable innovations. Such demonstrations encourage producers to invest in the enterprises.

Methodology

An additional constraint that is clearly an important prerequisite for efficient small ruminant production systems is methodology. The methodology must be of a type that can be applied successfully and can further stimulate expansion in small ruminant production.

This is especially the case with mixed crop - small ruminant systems, such as those that have been described in Table 5. If improvements are to be made within the totality of small farm systems in Asia, where mixed crops and animal systems are characteristic, an understanding is needed of the prevailing farming systems, the efficient use of the production resources, the injection of additional resources, and the requirements of the extention approach. De Boer (1985) suggests four consecutive stages: descriptive or diagnostic stage, design stage, testing stage, and the extension stage.

CONCLUSIONS

Small ruminant production systems in South and Southeast Asia are primarily traditional systems. Within these, goats and sheep occupy a secondary position in the complexity of small crop-livestock systems. The prevailing lack of incentives, inadequate understanding of the components of production systems, and, more particularly, inadequate application of potentially valuable technological interventions, suggests that a significant expansion in the productivity from goats and sheep is unlikely if the present trends are allowed to continue. Improvements are, therefore, urgently necessary and must efficiently use the production resources in systems that are demonstrably superior and potentially profitable. These improvements must be coupled to more intensive systems of production and to major shifts in resource use that can substantially increase the contribution by goats and sheep to the economy and food supply in the developing countries.

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FEED RESOURCES AND FEEDING SYSTEMS FOR SMALL RUMINANTS IN SOUTH AND SOUTHEAST ASIA

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Abstract *Small, integrated crop-livestock farms of the humid tropics have ample access to low-quality grasses and crop residues that contain low (2-10%) concentrations of crude protein (CP) and high (65-75%) concentrations of (neutral-detergent) cell well fibre (NDF). Such feeds are widely included in small ruminant diets. Because of their ready availability, their utilization should be maximized, but animal performance, especially of small ruminants with limited gastrointestinal capacity compared with metabolizable energy requirements, will be held to near or below maintenance levels if these feeds are not supplemented. High-quality supplements, however, are beyond the economic reach of small farmers, and their inclusion in small ruminant diets above low levels (15-20% of daily dry matter) will decrease rather than enhance utilization of the basal roughage. Many tree legumes, shrubs, foliages of certain food crops (such as cassava or sweet potatoes), and processing by-products (such as soybean curd sludge) are presently or potentially available to small ruminant holders. These materials contain intermediate concentrations of CP (15-25%) and NDF (35-45%) and their use as supplements will improve the rumen environment for maximal utilization of basal roughages while also allowing modest improvements in animal performance. Feeds of this category will maintain or improve total dry matter intake while adding rapidly digestible fibre, rumen-degradable protein, and escape protein to the diet. Possible problems as a result of antiquality factors (tannins, hydrocyanides, etc.) present in* *specific feed materials can be minimized by avoiding very high dietary levels of the problem feed. Dietary quality can also be enhanced by allowing sheep or goats maximum opportunity to select the more nutritious plant parts from the basal roughages, which can only occur if 50-100% more feed is offered than consumed each day.*

Small ruminants in South and Southeast Asia are held mainly by small, limited-resource farmers for whom crop production is the primary activity. In this context, livestock diets consist mainly of low-quality crop residues and forages from communal and fallow lands. Competition for land is a major constraint for livestock feed production and deficiencies have been noticed regionally (Hutagalang 1978; Devendra 1981) as well as on individual farms (van Eys et al. 1984). Many feed resources, however, are underutilized or used inefficiently; examples are agroindustrial by-products and the understory of plantation tree crops.

The primary factors limiting utilization of roughages by small ruminants are low intake and low digestibility. Physical and chemical treatments, especially of crop residues, can improve their nutrient composition; such methods, however, are generally not practical or economical (Jayasuriya 1983) and feeding treated roughages to small ruminants has given disappointing results (Ibrahim 1983).

In existing farming systems, supplementation strategies are the most appropriate way to increase small ruminant production. High-quality supplements, however, are limited in availability and their use is difficult to justify economically. Recent research has shown that many unconventional but locally available feedstuffs can be used successfully as supplements. This paper reviews the feed resources that are available in the South and Southeast Asian region and suggests ways to improve feeding systems for small ruminants in mixed crop-livestock systems.

FEED AVAILABILITY AND PRESENT DEGREE OF UTILIZATION

An overview of ruminant numbers and feed availability for the South and Southeast Asian region is shown in Table 1. Ruminant livestock numbers, and small ruminants in particular, have increased dramatically during the last decade. The increase in small ruminants averaged 35%, a rate of growth that

Table 1. Livestock numbers and feed availability in South and Southeast Asia.

Country	Livestock numbers (x 10^3)[a]				Permanent meadows and grassland (ha/AU)	Estimated feed availability (kg DM/AU per day)[b]		
	Cattle	Buffalo	Sheep	Goats		Fibrous crop residues	Forages[c]	Commercial concentrates
Bangladesh	3501 (137)	1644 (150)	1150 (108)	11800 (154)	0.02	6.5	2.7	0.45
India	182000 (101)	62000 (104)	41700 (104)	72000 (104)	0.04	7.0	1.5	0.18
Indonesia	6435 (104)	2506 (105)	4196 (129)	7985 (121)	1.05	9.4	36.3	0.78
Malaysia	555 (131)	295 (103)	66 (144)	385 (109)	0.03	25.3	1.0	0.96
Philippines	1950 (114)	2800 (103)	30 (100)	1600 (120)	0.03	10.7	7.1	0.36
Sri Lanka	1726 (100)	902 (112)	30 (103)	512 (93)	0.16	8.6	5.5	0.45
Thailand	4500	6150	22	32	0.03	9.4	1.0	0.60

Source: Adapted from FAO (1982).

[a] Index numbers are shown in parentheses (1972-1974 = 100).

[b] DM, dry matter; AU, animal unit.

[c] Derived from permanent pastures, grasslands, levees, roadsides, and communal lands.

is expected to continue (Remenyi and McWilliam 1985). Contrary to what one might expect, in several countries, livestock production has increased more rapidly than crop production: 24 vs 38%, respectively (FAO 1982). Although total feed availability is limiting in some countries, such as Bangladesh and India, for other countries, the problem seems to be in amounts and distribution of high-quality forages and concentrates.

While animal numbers have increased, production per animal has remained relatively constant. From the data on feed availability, one concludes that the increase in animal numbers has been supported largely by an increased utilization of crop by-products. With improved management and nutritional techniques, such feedstuffs could support an even larger population. Improving the present low degree of utilization of other available feed resources could lead to additional increases in animal production. Examples of underutilized resources are the areas under plantation crops (Mahyuddin and Hutagalung 1978) and unimproved grasslands (Ranjhan 1985). The latter are dominated by Imperata cylindrica and Themeda triandra and are more suitable for extensive grazing by large ruminants. The plantation crop areas, however, are an excellent potential source of forage for small ruminants, either under grazing or cut and carry systems.

The estimates on feed availability in Table 1 do not consider seasonal fluctuation in quantity and quality, nor do they consider accessibility or social and economic constraints. Indeed, on a local scale, feed availability may be less a function of absolute availability than of cost in terms of labour and time. Monitoring small ruminant production in three Indonesian villages has shown that the daily amount of feed harvested for confined animals averaged less than 3% of the flock weight. In another region, grazing was limited to less than 4 h/day, with no additional feed supplied (van Eys et al. 1984). Under these conditions, animals have little opportunity for diet selection and their nutritional status is close to or below maintenance.

Qualitative and quantitative deficiencies in conventional diets forces exploring alternative feeding systems. The potential of using agroindustrial by-products, the wastes from extracting a primary agricultural product, is large. Extraction rates and production of some agroindustrial by-products are presented in Table 2. On the basis of these data it is

Table 2. Annual production of agroindustrial crop by-products (t x 10^3).

Crop	By-product	Extraction rate (%)[a]	Country Bangladesh	 India	 Indonesia	 Malaysia	 Philippines	 Sri Lanka	 Thailand
Banana	Fruit waste	30	199	1417	540	141	1230	-	608
Cassava	Tapioca waste	57	-	3173	7296	214	1311	285	1197
	Leaves	7	-	390	896	26	161	35	1470
Castor	Seed meal	49	-	148	-	-	12	-	16
Cocoa	Pod husks	70	-	-	11	32	3	1	-
	Cocoa shells	15	-	-	2	7	1	<1	-
	Bean residue	10	-	-	2	5	<1	<1	-
Coconut	Cake meal	38	30	1710	4589	454	3674	652	318
	Husks	25	20	1125	3019	30	2417	429	209
Coffee	Pulp (dried)	43	-	67	114	4	69	5	8
	Hulls	6	-	9	16	<1	10	1	1
Cotton	Seed meal	43	3	1127	4	-	4	3	35
Groundnut	Stem and leaves	49	12	2793	404	10	22	3	70
	Meal	55	13	3135	454	12	25	4	79
Maize	Germ meal	17	-	1105	646	2	591	4	511
	Bran	9	-	585	342	<1	313	2	270
Mango	Kernel meal	49	-	4165	167	6	19	36	-
Oil palm	Palm kernel meal	2	-	-	17	18	-	-	1
	Palm oil mill effluent	2	-	-	17	70	-	-	1
	Palm press fibre	12	-	-	68	109	-	-	1

(continued)

Table 2. Concluded.

Crop	By-product	Extraction rate (%)a	Country						
			Bangla-desh	India	Indo-nesia	Malaysia	Philip-pines	Sri Lanka	Thai-land
Papaya	Fruit waste	35	9	96	105	3	25	-	-
Pineapple	Waste	70	111	429	385	112	610	340	1277
Rice	Bran	10	2100	6800	3410	206	835	309	1750
Sesame	Cake	60	14	285	5	-	-	8	17
Sugarcane	Molasses	4	285	7346	872	34	840	15	1208
Sweet potatoes	Vines	30	208	450	630	20	315	38	107

Source: Adapted from FAO (1982).
a Extraction rates are from Hutagalung (1978) and Devendra (1981).

estimated that, per animal unit (AU), the amount of by-products available varies between 0.3 and 5.4 kg dry matter (DM)/AU per day in India and the Philippines, respectively. For the seven countries combined, the average production is 2.5 kg DM/AU per day. Although the nutritive value of some of these feeds is limited, the level of availability illustrates their potential for increasing animal production if they were used locally as supplements to roughage diets.

A number of factors limit the use of agroindustrial by-products for ruminants (Devendra 1981). The most important factor is the cost to small farmers. Research in Indonesia has shown that the willingness of farmers to pay for improvements in nutrition is generally below their cost, even for a relatively inexpensive mineral supplement (Amir et al. 1986). Additional limitations may be in their physical form combined with problems of transport. Some of these by-products, however, are produced by small, local industries and should, therefore, be available to neighbouring farmers.

As a consequence of their limited ability to use agroindustrial by-products, the options for farmers to supplement basal roughage diets are limited to a few high-quality forages and the foliage from trees and shrubs. In chemical composition, many of these forages compare favourably with agroindustrial by-products. In the case of legume foliage, there is the additional advantage that they can be easily introduced into present intensive agricultural systems. Farmers, in general, recognize the relatively high feeding value of legume tree foliage and certain crop by-products such as cassava leaves and sweet potato vines. At present, however, incorporation of these feeds in small ruminant diets is limited and mostly inefficient. Rather than using these feeds as supplements, they are frequently fed as the sole feed between long periods of unsupplemented roughage feeding (van Eys et al. 1984).

This situation, in which relatively large quantities of low-quality roughages and limited amounts of high-quality feedstuffs are available, provides the main argument for basing improvements in feeding systems on existing roughages. The primary objective will not be to formulate balanced diets but rather to maximize utilization of the basic feed resources through the incorporation of small quantities of medium- to high-quality supplements.

QUALITATIVE ASPECTS OF SMALL RUMINANT FEEDSTUFFS

Crop by-products and forages that routinely make up the basal diet of small ruminants have high concentrations of structural components. Total cell wall constituents or neutral-detergent fibre (NDF) in fibrous crop residues is generally higher than 65% and acid-detergent fibre (ADF) is generally above 40%. Values for crude protein (CP) range from 2.5 to 6.0% (Hogan and Leche 1983). Information on the digestibility of untreated fibrous crop residues is limited, particularly for small ruminants. Existing data show considerable variability because of differences in variety, harvest, storage, and level of feeding. Ibrahim (1983) found the in vivo organic matter digestibility of straws to be rarely higher than 45% and dry matter intake of untreated straws and stalks by sheep to be generally lower than 45 g/kg $W^{0.75}$.[1] Compared with large ruminants, sheep and goats have a lower capacity to consume and utilize fibrous crop residues (Demment and Van Soest 1983); their intake level will rarely exceed maintenance.

Where sufficient amounts of green forage are available, crop by-products represent only a small portion of the diet. For instance, under mixed farm conditions in West Java, Indonesia, grasses represent 62-95% of the small ruminant diet and even when crop by-products were more readily available, they did not represent more than 2-11% of the diet (van Eys et al. 1984). Generally, low-producing species make up the grass fraction of the diets. Examples are Axonopus compressus, Paspalum conjugatum, Eleusine indica, and Ischaemum spp. (van Eys et al. 1983). When these native grasses are collected under the traditional cut and carry system, they contain relatively high levels of NDF (>60%) and ADF (>40%), although CP and DM digestibility are frequently more than 10 and 60%, respectively (Prabowo et al. 1984; Pulungan et al. 1985).

The use of cultivated tropical forages in small ruminant diets is limited. Because of the limitations on land resources and the relatively low importance of the small ruminant enterprise, few efforts are made by small ruminant producers to grow improved grasses or legumes. Where cultivated grasses are used, they are frequently cut at advanced maturity, resulting in a nutritive value similar to or lower than that of native grasses. The stemmy nature of many introduced grasses further reduces their utilization.

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[1] $W^{0.75}$ refers to metabolic weight.

Roughage diets must be supplemented with feeds of higher nutritive value if animal growth and reproduction are to be improved. The composition of some by-products and foliages that can be used as supplements to low-quality roughages are shown in Table 3. The list is not exhaustive and additional feedstuffs must be considered depending on agricultural practices and the prevalence of certain tree or shrub species. Composition of these feeds will vary with source, extraction procedure, and storage. On the basis of NDF and CP concentrations, they have been classified as energy or protein supplements.

It must be realized, however, that a conventional analysis of feedstuffs is of limited use for diets that are based on low-quality roughages. Ideally, CP, NDF, and major minerals should be further qualified to determine site and extent of digestion. This information is largely lacking and must be inferred from their composition and origin. Nevertheless, level of structural components and antiquality factors do provide important information on digestibility and intake.

Although access to energy and protein concentrate feeds may be limited for most small-scale farmers, foliage of shrubs and legume trees are readily available and can be obtained at little or no cost. Most of the tree leaves and roughage supplements are used to some extent by small-scale farmers (Hutagalung 1978; van Eys et al. 1984).

In chemical composition, forage supplements compare favourably with agroindustrial by-products. Many concentrate supplements provide high levels of either energy or protein. As supplements to roughage diets and to provide a balanced diet, a mixture of the protein and energy sources is needed. Forage supplements, however, are good sources of both energy and protein.

The content of structural carbohydrates in many of the forage supplements is high. At high feeding levels, this may interfere with utilization of the roughage as well as the supplement. From a caloric point of view, energy supplements are often classified as such because of their high levels of ether extract, which may also limit the level at which they can be used in roughage-based diets. The calcium to phosphorous (Ca:P) ratio of concentrate supplements is often too narrow,

Table 3. Chemical composition of supplementary feeds.

Feed	Dry matter (%)	Composition of dry matter (%)[a]							Suggested level of feeding	Antiquality factors
		CP	EE	NDF	CF	ME(kJ)	Ca	P		
Energy feeds										
Banana fruits	21	5	2	-	3	-	0.2	0.1	25	Tannins
Cassava meal	85	3	1	11	-	2.92	0.1	0.1	25	HCN
Cassava pomace	26	2	1	27	-	2.91	0.7	0.1	40-50	HCN
Cassava peelings	23	5	1	-	7	2.59	2.2	0.4	20-30	HCN
Cocoa pod husks	90	6	1	-	32	1.69	0.5	0.7	30	Caffeine, theobromine
Cocoa shells	92	20	17	-	7	3.12	0.2	0.2	30	Caffeine, theobromine
Coffee pulp	23	10	2	-	29	2.25	0.6	0.1	20	Tannins, caffeine
Corn bran	86	11	8	-	5	3.26	0.1	0.7	20-30	
Citrus pulp	20	7	3	-	13	3.2	0.7	0.1	30	Urinary calculi
Molasses	75	1	-	-	-	2.63	0.2	-	25	
Palm press fibre	86	4	21	-	36	1.69	0.3	0.1	?	
Pineapple waste	87	5	2	73	26	2.58	0.2	0.1	-	
Rice bran	90	15	14	33	12	2.30	0.2	1.4	25	Oils, urinary calculi
Rice polishings	90	14	17	-	4	3.21	0.1	1.5	?	
Sago (wet)	20	2	1	-	6	3.10	-	-		
Sago refuse	77	3	-	-	10	2.61	0.4	-		
Protein feeds										
Castor seed meal	89	10	2	-	23	2.30	0.4	0.2	5	Ricinoleic acid
Coconut cake meal	92	22	7	-	13	3.20	0.2	0.7	30	Oils

(continued)

Table 3. Continued.

Feed	Dry matter (%)	Composition of dry matter (%)[a]							Suggested level of feeding	Antiquality factors
		CP	EE	NDF	CF	ME(kJ)	Ca	P		
Protein feeds (cont.)										
Cotton seed meal	92	41	5	-	16	2.80	0.2	1.0	30	
Ground nut cake	83	52	6	14	8	3.25	0.2	0.6	30	
Kapok seed cake	86	36	4	-	30	2.18	0.5	1.0	30-40	Cyclopropenoid acid
Palm kernel cake	91	19	2	-	16	3.31	0.3	0.6	30-40	Oils, palatability
Palm oil mill effluent	5	11	21	-	12	-	0.5	0.8	20	Oils, palatability
Rubber seed meal	89	26	11	-	4	4.34	0.1	0.5	20	HCN, palatability
Soybean curd sludge	13	21	-	52	24	-	0.5	0.2	40-50	
Soy sauce refuse	38	27	8	26	6	-	-	-	40	Sodium
Forages										
Acacia leaves	32	20	2	-	20	2.09	1.0	0.2	?	Possible: HCN, tannins, fluoroacetic acid, oxalate
Algaroba leaves	25	24	3	45	25	-	0.9	0.3	?	
Albizia foliage	37	24	5	37	-	-	1.4	0.1	25	Tannins (2-3%)
Calliandra foliage	39	24	4	24	-	-	1.6	0.2	25	Tannins (10-14%)
Cassava leaves	24	28	3	34	12	2.52	1.2	0.5	25	HCN, tannins
Erythrina foliage	13	34	-	41	-	2.50	1.5	0.4	-	

(continued)

Table 3. Concluded.

Feed	Dry matter (%)	Composition of dry matter (%)[a]							Suggested level of feeding	Antiquality factors
		CP	EE	NDF	CF	ME(kJ)	Ca	P		
Forages (cont.)										
Ficus foliage	32	14	3	-	22	1.42	4.6	0.5	-	
Glyricidia foliage	26	27	4	50	15	2.66	1.6	0.3	75	
Indigofera herbage	23	17	1	-	32	1.97	4.3	0.2	50	Indospicine, 3-nitropropanic acid
Soybean straw	80	14	3	78	36	2.66	0.9	0.2	-	Cell wall constituents
Jackfruit leaves	33	16	4	32	17	2.02	1.6	0.4	-	
Leucaena foliage	28	27	4	38	21	2.13	1.4	0.2	60	Mimosine
Sesbania foliage	23	28	5	37	17	2.44	1.3	0.5	-	
Sweet potato vines	9	22	3	36	15	2.39	1.8	0.2	?	Low dry matter
Water hyacinth	6	16	4	43	25	2.22	1.6	0.6	25	Nitrates, oxalates, low dry matter

[a] Expressed as a percentage of the total dry matter intake and based on the antiquality factor listed or digestion of neutral-detergent fibre. CP, crude protein; EE, ether extract; NDF, neutral-detergent fibre; CF, crude fibre; ME, metabolizable energy.

and an additional source of Ca will be needed. Tree legume foliage may be useful in correcting the imbalance.

If these feeds are to be used as supplements to roughages, they must be fed at levels that ensure an increase in animal performance while maintaining high intakes of the roughage component. Consequently, the level of antiquality components should not affect animal performance or digestion of the febre fraction. The recommended levels of feeding are, therefore, primarily based on the level and effect of the deleterious substances. A secondary consideration is the effect of the supplement on fibre digestion.

The list of known deleterious substances that should be considered is extensive. There is, however, a paucity of information on the nutritional and subclinical effects of periodic ingestion of a single dose of tannins, cyanogenic glucosides, nitrates, or soluble oxalates. Few of the supplements listed will cause acute toxicity at infrequent feeding of moderate amounts, but continuous ingestion may reduce productivity. The risks of acute toxicity are larger for free-grazing and browsing animals.

Because many of the supplement feeds have not been used until fairly recently, the full range and number of antiquality components have not been identified. This is especially true for shrub and tree leaves that have a higher proportion of secondary compounds than concentrate feeds. In part, this problem is related to the fact that foliages are commonly offered in fresh form, whereas the concentrate feeds are the product of extensive extraction, drying, and storage treatments.

Certain compounds can be partially destroyed by drying and storage, most notably the cyanogenic glucosides in cassava leaves (Oke 1978). A series of studies in which cassava leaves were fed to small ruminants suggests that wilted or dried cassava leaves can be fed to a maximum of 25% of dietary DM (Mathius et al. 1983). When higher levels were used, lamb and kid growth did not improve, even with the inclusion of additional protein and energy (Mathius et al. 1984; Mathius et al. 1985).

A discussion of all the antiquality factors and their specific effects is beyond the scope of this paper. Some general observations, however, are appropriate, especially with regard to forage supplements. With forages, it is important to consider their stage of maturity. Nitrogenous toxins such as cyanoglucosides, amides, alkaloids, and certain amino acids are commonly present in highest concentration in meristimatic tissue. Although young material has a higher nutritive value, feeding of more mature foliage will reduce the risk of toxicity.

Ruminants are uniquely suited to utilize feeds that contain potentially deleterious compounds because of detoxification in the rumen. A case in point is the mimosine in Leucaena leucocephala. In certain parts of Southeast Asia, ruminants are able to detoxify the mimosine metabolite DHP (3-hydroxy-4[1H]-pyridone) (Hegarty et al. 1985). Similarly, oxalates and nitrates can be deactivated to some extent in the rumen.

There is a wide presence of tannins in leguminous foliage. High levels of tannins will depress palatability, voluntary intake, and carbohydrate digestion in the rumen. The same compound, however, can be effective in reducing ruminal plant protein degradation and increasing the supply of feed amino acids to the duodenum (Barry and Reid 1984). Ideally, the total amount of feed tannins will be balanced so that DM intake and digestibility will not be affected, while rumen bypass protein will be maximized. This is difficult to attain, however, when the supplement consists of a single plant species.

The wide presence of antiquality components underscores the necessity of developing feed systems that incorporate low supplementation levels. The extent to which different toxic compounds are additive in their effect on animal productivity is not known, but inclusion of two or more supplements with different toxins may allow for a higher total level of supplementation than that possible with a single supplement.

FEEDING SYSTEMS

The validity of applying traditional feeding standards to ruminants under the conditions of countries in the humid tropics has been questioned (Leng and Preston 1983). Quantitative and qualitative limitations to the available feed resources make the conventional balancing of diets difficult. Nutrient requirements and feed values established under temporate conditions are frequently not applicable to the digestion and metabolism of feeds composed predominantly of structural carbohydrates. Under small farm conditions in the humid tropics, the primary objective should be to optimize the utilization of the roughage component, which means maximizing microbial activity and ruminal digestion. The second objective should be to provide sufficient additional nutrients to increase intake of the basal diet and to stimulate growth and reproductive efficiency.

Maximizing Ruminal Digestion

Maximum fermentation of plant cell wall carbohydrates in the rumen requires an environment that will provide all essential nutrients for growth of cellulolytic bacteria. With low-quality roughages, one of the major limitations to microbial digestion is the level of dietary nitrogen and the resulting low levels of rumen NH_3. The optimum ammonia N level for maximum DM digestibility has been established at 24 mg/100 mL (Mehrez et al. 1977). Ammonia N concentrations estimated to support maximum microbial growth are lower; values of 5 mg/100 mL appear adequate (Satter and Roffler 1977). It is generally accepted that 2.5 g feed N/100 g digestible organic matter (DOM) will ensure adequate levels for fibre digestion, thus reducing the intake-depressing effect of rumen fibre fill (Allden 1981). On this basis, a diet of 50% digestibility would require a feed N concentration of 1.25%. Available N levels in many fibrous crop by-products are much lower and N supplements will be necessary.

Numerous reports describe the beneficial effects of additional soluble N in the form of urea or related compounds with straw diets. On fresh forages, however, rumen NH_3 levels appear adequate. Studies on the NH_3 concentration in the rumen of animals fed common tropical forages are limited. Rumen NH_3 levels, however, are related to the amount of nonprotein nitrogen and highly soluble protein in feeds. The high level of soluble N in grasses (Table 4) strongly suggests that ruminal NH_3 levels will be adequate if they are fed immature tropical forages. The stimulatory effect of green forage on the digestibility and intake of rice straw diets (Preston 1981) may, in part, be related to the contribution of these forages to the rumen N pool. Furthermore, the less rapidly degradable N components, particularly dominant in legumes, may provide for continued high rates of ruminal digestion for hours after ingestion has ceased and the more soluble N has been exhausted. This aspect of N supplementation may be important in cut and carry systems where animals are fed only once or twice daily.

In addition to NH_3, rumen microbes need small amounts of amino acids, peptides, sulfur, and possibly other growth factors. The need for providing these nutrients does not seem to be limited to low-quality crop residue diets. When fresh *Pennisetum purpureum* of 6-8 weeks regrowth was supplemented with tree legume foliage, the beneficial effects in terms of protein could not be attributed solely to an increase in supply of feed nutrients to the small intestine (van Eys et al. 1986).

Table 4. Protein content and solubility of tropical herbages.

	Regrowth (weeks)	Total protein (%)	Protein solubility (%)	Reference[a]
Soluble in Burroughs mineral solution				
Grasses				
Chloris gayana	6	13.4	28.8	1
Pennisetum clandestinum	6	17.5	35.2	1
Setaria anceps	6	10.1	28.9	1
Digitaria decumbens	6	8.8	27.8	1
Panicum coloratum	6	12.1	39.9	1
Brachiara mutica	6	13.9	40.8	1
Legume				
Leucaena leucocephala	-	31.8	21.1	2
Rumen soluble after 2 h				
Grass				
Pennisetum purpureum	6-8	11.9	45.6	3
Legumes				
Leucaena leucocephala	12-14	26.9	27.4	3
Gliricidia maculata	12-14	25.9	27.5	3
Sesbania grandiflora	12-14	28.1	42.5	3

[a] 1, Aii and Stobbs (1980); 2, Flores et al. (1979); 3, van Eys et al. (1986).

In addition to an increase in dietary protein, legume supplementation may have shifted volatile fatty acid production in favour of propionate and stimulated microbial protein production. It must be recognized, however, that the effect of legume supplements on ruminal degradation of fibre is confounded by their effect on turnover rate. Legume supplementation of roughage diets accelerates turnover (Thornton and Minson 1973) and, consequently, increases the efficiency of microbial protein production.

Supplementation with high levels of rapidly digestible carbohydrates will result in a decrease in digestibility, attributable to a shift in microbial population and ruminal pH. Feeding concentrates with high levels of soluble carbohydrates stimulates growth of starch-digesting microbes at the expense of cellulolytic microorganisms (El Shazly et al. 1961). Depending on the basal diet and type and level of supplementation, however, the effect on digestibility may be minimal. Energy supplements that have a slow rate of ruminal digestion and that do not drastically affect saliva production will have less of an effect on fibre digestibility. Feeding a supplement of this type at up to 25% of DM intake does not seem to affect roughage utilization.

Mineral supplementation may be necessary to stimulate rumen digestion of fibrous crop by-products (Leng and Preston 1983). Fresh green forages, however, will generally provide adequate levels of soluble minerals for maximum microbial activity (Durand and Kawashima 1980).

Optimizing Nutrient Composition of Digestion Products

On roughage diets, maximizing rumen microbial activity will provide sufficient nutrients to the duodenum for low levels of animal production. To meet requirements for higher growth rates, pregnancy, or milk production, especially for highly prolific breeds, additional nutrients are needed. Maximal roughage utilization should remain the cornerstone of practical feeding systems and the supplements that will provide nutrients over and above those produced by rumen digestion should maintain or improve intake of the basal diet.

Requirements of high-producing animals for amino acids cannot be met solely by the microbial protein produced from the ruminal digestion of roughages. Undegraded feed protein must be provided as an additional source of amino acids. Degradability of protein in the rumen is directly related to the extent and rate of in vitro protein solubilization in rumen fluid. Information on protein degradability of tropical feedstuffs is quite limited. Because of the interest by producers in temperate climates in concentrate feeds of tropical origin, such feeds have received the most attention. For example, rumen degradability of mechanically extracted cottonseed meal is about 40%. For peanut meal and soybean meal, however, the corresponding value is higher than 70%. Feeds of animal origin generally have low (<35%) degradability in the rumen.

The tropical oilcake meals, on average, are good sources of bypass nutrients, partly because of high lipid levels (Leng 1985). For the same reason, rice polishings, rice bran, cacao shell meal, and corn bran may also be good sources of nutrients that escape rumen fermentation.

The data presented in Table 5 are the result of Dacron bag studies and show that the protein of specific by-products and tree legume foliages less soluble than that of tropical grasses. Consequently, the tree and shrub leaves, especially from leguminous plants, may provide significant amounts of rumen bypass protein. There is, however, considerable variability in protein degradation among feeds of this type. This may be a result of differences in variety, growth stage, plant parts, and storage. For legume tree foliage, such as *Gliricidia* and *Erythrina*, the effect of plant part (leaf vs petiole or young shoot) and growth stage appear to be small (Espinoza 1984). The largest source of variability in N solubility is plant species, which is easily exploitable for small ruminant feeding systems.

The proportion of supplementary protein that can escape rumen fermentation will depend on the basal diet. Rumen retention time is a major determinant of the extent of protein degradation. Since the inclusion of legumes in roughage-based diets may increase the rate of passage, both the proportion of protein escaping rumen fermentation and the efficiency of microbial protein production may also increase. Furthermore, tannins present in many of tropical legumes (Hegarty et al. 1985) may reduce ruminal degradation of plant protein.

The utilization of bypass protein is partly controlled by energy availability (Storm et al. 1983). On roughage-based diets, these are largely derived from ruminal digestion. For high-producing animals, fermentation alone seldom provides sufficient energy to meet animal requirements for glucose or

Table 5. Parameters of ruminal degradation of the nitrogen fraction in six tropical forages.

Forages	Initial solubility (%)	Degradation rate (%/h)[a]	Potential availability (%)
Cowpea straw	8.9	15.5	77.8
Leucaena foliage	18.5	18.5	93.1
Cassava leaves	39.7	10.1	91.0
Sweet potato vines	28.1	12.9	92.2
Erythrina foliage	47.0	12.7	92.8
Gliricidia foliage	32.8	11.3	89.3

Source: Roldan (1981).

[a] Includes initial solubility and is based on disappearance between 0 and 96 h.

gluconeogenic compounds (Leng 1985). This deficiency will be only partially corrected by increased supplies of amino acids at the duodenum, and a source of digestible carbohydrates that will escape rumen fermentation may also be of benefit.

EFFECTS OF SUPPLEMENTATION ON VOLUNTARY INTAKE

Supplementation of high-fibre diets with a feed of higher quality invariably results in an increase in total DM intake. Changes in intake of the basal diet, however, will be influenced by the composition and physical form of the supplement.

When high levels of concentrate supplement are used, a depression in plant cell wall digestibility is accompanied by a reduction in roughage intake because of an increase in fibre fill. Because low levels of concentrate supplementation have only a minor effect on cell wall digestibility, reductions in intake are not observed when supplements are kept below 20-30% of total DM intake.

Forage supplements or supplements with high levels of NDF will usually decrease the intake of the basal diet. In certain instances, however, such as feeding at very low levels (<10-15% of DM intake), intake of the basal diet may improve, although this response is generally smaller than with a concentrate supplement. In studies where tree legume foliages have been compared with concentrates, the intake of the basal diet was consistently higher with the concentrate supplement (Flores et al. 1979; van Eys et al. 1986). In terms of rumen fill, the different response between concentrate and forage supplements may, in part, be a result of the time delay associated with particle size reduction, which is larger on forage diets. With forage supplements, the effect on fibre digestibility is normally small and the depression in intake of the basal diet occurs mainly because of a replacement effect.

The importance of physical form and fibre content on DM intake is illustrated in Fig. 1. In this experiment, isonitrogenous levels of concentrate and forage supplement were compared with respect to their effect on DM intake. At low levels of supplementation, hay intake by sheep and goats was increased by cottonseed meal inclusion but did not change significantly with alfalfa. At the higher level of supplementation, differences in hay intake between the two supplements persisted, resulting in higher intakes for concentrate-supplemented animals.

These results illustrate one of the limitations associated with forage supplementation of roughage diets. As levels of

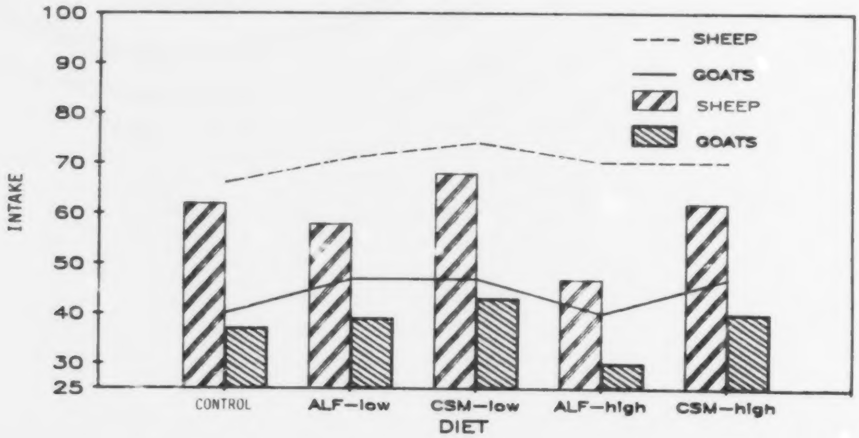

Fig. 1. Intake (g/kg metabolic weight) of total dry matter (lines) and bermuda grass hay (bars) by lambs and kids supplemented with alfalfa (ALF) or cottonseed meal (CSM).

forage supplementation increase, intake of the basal diet will decrease in a nearly proportional fashion and increases in total DM intake may be small. Furthermore, because of the difference in nutrient density between concentrates and forages, a larger amount of good-quality forage is required to meet the same level of nutrient intake. Nevertheless, because of economic reasons, forages will, for the time being, remain the supplement of choice for many small ruminant producers in the region.

Where agroindustrial by-products can be obtained at minimal cost, they can play an important role in meeting nutrient requirements of the animal as well as maintaining a high intake of the roughage. Although many of these feeds have a relatively high level of NDF, digestion characteristics of the fibre limit their effect on fibre fill and intake. An important example in this respect is soybean curd sludge (SBCS). Despite a 50-55% NDF content, SBCS increased total DM intake without reducing the intake of a native grass mixture at supplementation levels of 40% of the total DM (Pulungan et al. 1985). Total DM intake continued to increase as SBSC increased to 60% of the total DM diet. Much of this response can be attributed to the high rate and extent of digestion of SBSC fibre in the rumen. Many other agroindustrial by-products may give similar results. The fact that they are frequently produced in small quantities as part of cottage industries make them exceptionally suitable for use in small ruminant feeding systems.

CONCLUSIONS

A review of the feed resources and ruminant numbers in South and Southeast Asia suggests that, despite limits to the availability of good-quality forages and conventional concentrates, large amounts of crop residues and agroindustrial by-products are available. At present, these feed resources are underutilized, but development of improved supplementation strategies may substantially increase animal productivity as well as utilization of available roughages.

For small ruminants, the use of crop by-products is restricted by their relatively low capacity to handle poorly digestible fibre. If possible, the basal diet for small ruminants should consist of fresh forages with an NDF concentration below 55-60%.

Improved feeding systems must be based on maximizing rumen digestion of the basal diet and the strategic use of supplements to provide nutrients that escape rumen fermentation. To maintain a high intake of the basal diet, supplements should be fed at low to intermediate levels, particularly if the supplement is a forage. Such systems of small ruminant feeding offer a practical solution to demands for improved production and can be realized with the available animal resource. Under the existing condition of large supplies of low-quality roughages and limited supply of supplements, nutrient requirements for maximum production can rarely be met and improved animal output will more likely result from increases in numbers and reproductive performance, along with modest improvements in growth rates.

The complex interactions and limited understanding of factors involved in the utilization of low-quality roughages frustrates the development of more efficient feeding systems. For small ruminant producers, supplementation strategies offer a practical means to increase production with existing resources. Further research is needed, however, to improve our understanding of the factors limiting roughage utilization.

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PRODUCTION SYSTEMS BASED ON ANNUAL CROPPING

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Abstract *The major annual crops grown in South and Southeast Asia are rice, maize, sorghum, millets, sesame, sugarcane, peanuts, soybeans, cassava, and sweet potato. In 1983, the total crop area harvested was* 169×10^6 *ha, resulting in huge quantities of crop residues. The quantitative and qualitative aspects of residues from these crops for feeding to small ruminants are reviewed. Native and sown species of grass, herbaceous legumes, and tree legumes can be utilized to supplement these crop residues. The utilization of these various sources of feed and opportunities for increased animal production in irrigated rice, rain-fed rice - dryland cropping, and dryland cropping - mixed garden systems are discussed. It is concluded that, although there is a lot of knowledge available on production and qualitative aspects of these feeds, there is little information on feeding systems practiced by farmers or the assessment of socioeconomic benefits from technological innovation in crop-livestock systems.*

The majority of farmers in South and Southeast Asia are smallholders (Devendra 1983). This is especially true in areas of intensive annual cropping where farm areas are often less than 1 ha. Although crop production is the dominant farm activity and source of income, livestock raising or ownership is also an important associated activity of the typical Asian smallholder farmer. In cropping regions, livestock populations have been traditionally dominated by cattle and buffalo because they provide draft power for the farmer, but recent trends show that small ruminant numbers are increasing and to some extent replacing large ruminants on smallholder farms (Remenyi and McWilliam 1985).

The reasons for raising small ruminants may include the production of meat for sale or consumption, milk production from goats, social status, ceremonial requirements, low feed requirements, simple housing needs, or to diversify or increase the flexibility of farm income. Mutual benefits are obtained by the inclusion of ruminant livestock in cropping systems, the most obvious of which is that livestock can utilize crop residues and by-products and return manure to the cropland. The successful integration of annual crop and livestock production demands an understanding and strategy for utilizing the crop residues and by-products that become available throughout the year and the supplementation of these with other sources of feeds, chiefly forages, that overcome the dietary deficiencies of these crop residues. In this paper, emphasis is given to the characterization of the major crop residues in the region in terms of their qualitative and quantitative aspects and the way in which different types of crops and alternative sources of forage can be integrated to provide a readily available and continuous supply of feed for small ruminant production.

In 1983, the total small ruminant population in the South and Southeast Asia region was roughly 74 million sheep and 132 million goats (Table 1). The largest small ruminant populations in the region, however, were found in India, which had 57% of the sheep and 59% of the goats, and Pakistan, which had 31% of the sheep and 21% of the goats. In Southeast Asia, only Indonesia had a large population of either sheep or goats.

It is difficult if not impossible to determine the proportion of the small ruminant population that is associated with annual cropping systems. In general, higher sheep and goat populations are found in less-intensive farming systems, drier regions, and upland or hilly areas that do not favour cultivation. In Java, for example, where 75% of the land is cultivated, there is a tendency for small ruminant livestock density to increase with increasig altitude (Table 2). The lower density in upland rice - mixed grasslands is associated with greater areas of forest and tree crops. In the Philippines, which has the second-largest goat population in Southeast Asia, goats seem to be mainly associated with the drier, upland areas (Godilano and Dabu 1985).

Table 1. Sheep and goat populations in South and Southeast Asia, 1974-1983.

	Sheep (x10^3 head)				Goats (x10^3 head)			
	1974-76	1981	1982	1983	1974-76	1981	1982	1983
Bangladesh	1067	1070	1080	1090	7676	11800	11900	12000
Bhutan	39	41	42	43	38	43	44	45
Brunei	-	-	-	-	1	1	2	2
Burma	187	250	255	260	539	769	770	770
India	40000	41500	41700	41700	72500	77200	77500	78000
Indonesia	3253	4177	4231	4300	7252	7790	7891	7900
Kampuchea	2	1	1	1	1	-	1	1
Laos	-	-	-	-	31	54	56	58
Malaysia	46	68	66	66	352	340	350	350
Nepal	2303	2420	2450	2480	2427	2600	2620	2650
Pakistan	17493	22115	22812	23531	20016	25842	26763	27716
Philippines	30	30	30	30	1333	1696	1783	1859
Singapore	-	-	-	-	2	3	3	3
Sri Lanka	29	30	28	28	552	512	512	515
Thailand	49	21	22	22	30	38	32	30
Vietnam	11	15	16	18	190	170	197	200
Total	64509	71738	72733	73569	112940	128858	130424	132099

Source: FAO production yearbooks.

Table 2. Small ruminant density in Indonesia according to land use classification.

Land use class	Small ruminant density (head/km)	Human population density (head/km^2)	% of land <100 m altitude	Annual rainfall (mm)
Rice (mainly irrigated)	77	1110	90	1500-2000
Rice (rain fed)	89	1040	56	2000-2500
Rice, dryland crops	92	638	46	1500-2000
Rice, mixed crops	77	621	26	>3000
Dryland crops, rice	129	664	11	2500-3000

FEED RESOURCES IN ANNUAL CROPPING SYSTEMS

The dominant farm activity and source of income in annual cropping systems is from crops. The introduction and integration of ruminant livestock into these systems must not, therefore, require a major change in emphasis in the farming program. Livestock production must be based on the utilization of existing crop residues, forages from noncropped areas of the farm, regrowth of crops and weeds following crop harvest, and the supplementation of these feed resources by special-purpose forages where necessary.

It is extremely difficult to quantify yields and nutritive value of these possible feed resources as they vary with variety, growth stage, soil and environmental conditions, and agronomic practices. The values subsequently quoted can only provide a guide to the quantity of forage that may be available and some indication of their feeding value and need for supplementation with other feed resources to provide a well-balanced diet.

Crop Residues and By-Products

In 1983, the harvested area of the 10 major annual crops in the South and Southeast Asia region was 169 x 10^6 ha (Table 3). Wetland rice (paddy) was sown on a greater area than all other crops collectively, with millets, sorghum, and maize being the second most important group of crops, although millets and sorghum were only grown extensively in India. Among the leguminous crops, peanuts (groundnuts) were the most important crop in the region. Yields of all crops vary greatly between and within countries (Table 4), with the result that yields of crop residues available for ruminant feeding will also be highly variable. In this section, a summary is given on quantitative and qualitative values of the important annual crop residues available for feeding to ruminant livestock, with emphasis where possible given to small ruminants.

Rice (*Oryza sativa*)

The majority of rice grown in the region is wetland rice grown under irrigated or rain-fed conditions with only small areas of upland rice. The average yield of rice in the region is 2400 kg/ha (Table 4), with variation between countries from 1000 to 3400 kg/ha. The dry weight ratio of rice straw to grain yield is about 1:1, depending on variety, growing conditions, and harvesting method, thus providing similar yields of rice straw. Straw yields of up to 9500 kg/ha have, however,

Table 3. Area of major annual crops harvested (ha x 10^3) in South and Southeast Asia during 1983.

	Wet rice	Maize	Millet	Sorghum	Sesame	Soybean	Peanut	Sugar-cane	Cassava	Sweet potato
Bangladesh	10600	2	-	-	40	-	23	165	-	66
Bhutan	30	59	9	-	-	-	-	-	-	-
Brunei	3	-	-	-	-	-	-	-	1	-
Burma	4700	196	185	-	796	27	623	56	6	4
India	41000	6000	17500	16500	2600	750	7500	3365	322	215
Indonesia	9100	3200	-	5	25	730	475	271	1400	270
Kampuchea	1755	35	-	-	10	1	6	4	10	3
Laos	670	32	-	-	-	6	12	1	5	3
Malaysia	700	8	-	-	-	-	6	19	35	4
Nepal	1290	460	118	-	-	-	-	24	-	-
Pakistan	2020	780	547	400	30	4	69	912	-	1
Philippines	3300	3400	-	-	-	11	55	480	210	210
Sri Lanka	926	27	23	-	32	2	15	8	62	17
Thailand	9400	1688	-	265	37	128	130	577	1300	40
Vietnam	5900	380	-	31	27	100	140	100	485	382
Total	91394	16267	18382	17202	3597	1759	9054	5982	3836	1215

Source: FAO production yearbook, 1984.

Table 4. Area yields (kg/ha) of major annual crops harvested in South and Southeast Asia during 1983.

	Wet rice	Maize	Millet	Sorghum	Sesame	Soybean	Peanut	Sugar-cane	Cassava	Sweet potato
Bangladesh	2047	625	-	500	513	763	1152	44366	-	10455
Bhutan	2000	1400	800	-	-	-	-	-	-	-
Brunei	3384	-	-	-	-	-	-	-	5515	-
Burma	3085	1537	643	-	257	-	1109	55779	9182	4000
India	2195	1217	600	727	227	973	973	56208	15870	7263
Indonesia	3780	1250	-	600	320	808	1600	90448	9836	7852
Kampuchea	969	1714	-	-	500	1000	917	51714	7500	8333
Laos	1477	1200	-	-	-	793	797	30000	14800	10606
Malaysia	2857	1125	-	-	-	1600	3508	52632	10714	17436
Nepal	2127	1169	957	-	-	-	-	16667	-	-
Pakistan	2579	1282	494	588	400	419	1217	35684	-	14815
Philippines	2470	996	-	-	-	1091	909	44723	10952	5000
Sri Lanka	2376	926	652	-	418	1000	514	50000	9194	9524
Thailand	1972	2104	-	1234	696	984	1204	42289	13077	8987
Vietnam	2458	1105	-	1355	444	1070	621	4600	5567	4450
Mean	2385	1296	691	834	419	955	1210	43844	10201	9060

Source: FAO production yearbook, 1984.

been recorded experimentally in West Java (Sutjipto, personal communication). Rice hulls and rice bran are by-products that are also available. Rice hulls are not suitable for feeding to animals because of their high silica content and crude fibre (CF), but rice bran provides a valuable high-protein supplement for ruminant animals. The digestibility of rice straw is lower in sheep than in cattle or buffalo (Cheva-Isarakul and Cheva-Isarakul 1984) and can vary greatly (36.6-53.3%) depending on variety, season, and nitrogen fertilizer application to the crop (Roxas et al. 1985). The feeding value of rice straw can be increased by treatment with alkali materials, urea, molasses, and minerals. Extensive reviews have covered the treatment of straw for immediate use or long-term storage (e.g., Jackson 1978). The feeding value of rice straw can also be improved through the use of supplements that provide high levels of protein (e.g., legumes and cassava leaves) or energy (e.g., cassava by-products). This is especially true for small ruminants that require more fresh forage than large ruminants. In regions where rice is not irrigated or followed by another crop, rice regrowth can also provide a short-term fresh feed source for cutting or grazing.

Maize (*Zea mays*)

Maize (corn) is grown in all countries in South and Southeast Asia (Table 3). Yields average 1300 kg/ha, but vary from 600 to 1200 kg/ha (Table 4). Considerable variation is found in the literature on the ratio of dry weight residue to grain yield because of differences in stage of growth harvested, variety, and environmental and agronomic conditions. The ratio can vary from 0.8 to 4.9, thus providing a wide range in residue yields. Where maize is harvested for fresh cob consumption, the leaves and stems of the plant have a higher nutritive value for sheep and cattle (Johnson et al. 1984/85) than at maturity. From the soft dough stage of grain development, the top of the maize plant can be removed above the ear without any effect on grain yield. This provides a valuable source of green material for feeding to livestock. The mature corn stover can be made into silage for long-term storage. The addition of molasses to corn silage increases the crude protein content and digestibility (Lopez 1985). The organic matter digestibility (OMD) and TDN value of sweet maize stalks appear much higher than rice straw when fed to sheep, cattle, and buffalo (Cheva-Isarakul and Cheva-Isarakul 1984).

Millets (various species)

Millets are mainly grown in the Indian subcontinent and Burma. The term "millets" describes a wide range of species that includes *Pennisetum americanum*, *Eleucine coracana*, *Panicum miliaceum*, *Panicum sumatrense*, *Echinochloa crus-galli*, *Echinochloa frumentacea*, *Paspalum scrobiculatum*, and *Setaria italica*. The main millet species are, however, *P. americanum*, *E. carocana*, and *P. miliacenum*. The chemical composition of *P. miliacum* is similar to maize and corn residues, but its digestibility is higher (Table 5). Millets have a potential for feeding to ruminant animals as a green forage if the seasonal conditions are unfavourable for grain production. Average yields of grain are 700 kg/ha and the yield of hay residues can be up to 4 or 5 times the grain yields.

Sorghum (*Sorghum bicolor*)

The largest areas sown to sorghum are in India, with smaller areas in Pakistan and Thailand. The average yield of grain is 800 kg/ha. The ratio of stover yield to grain yield varies widely from 1:6 giving average residue yields of 800-4,800 kg/ha, although stover yields as high as 10,700 kg/ha have been recorded in Central Java (Sutjipto, personal communication). The CP content can be quite variable (Table 5) depending on variety and seasonal and agronomic conditions. Thus, the need for supplementation by high-protein forages can be variable. Shoots of sorghum contain the cyanogenic glucocide dhurrin, which hydrolizes to hydrocyanic acid (HCN), which is dangerous to livestock. The quantity of HCN varies with variety and growth condition and is usually highest in young plants or freshly ratooned plants, particularly following a period of drought.

Sesame (*Sesamum indicum*)

Sesame is an important crop in India and Burma, with smaller areas sown in Bangladesh, Pakistan, Sri Lanka, Thailand, and Vietnam. Average grain yields are only 400 kg/ha. Little information is available on the proportional yield of residues or their nutritive value.

Soybean (*Glycine max*)

Soybeans are grown widely in the region; the largest areas sown are in India and Indonesia. Average yields are 1000 kg/ha. During crop maturation, leaves senesce so that residues at harvest are usually 60% stalk and 40% pod. Some varietal differences occur in the amount of leaf fall and, together with other agronomic and environmental factors, cause the residue yield to vary from 2 to 3 times the seed yield. Because of these same factors there is considerable variability in the nutritive value of the crop residues (Table 5). With indeterminate varieties of soybeans, some farmers in Java cut

Table 5. Nutritive values, protein digestibilities and energetic values of the major annual crop residues in the South and Southeast Asian region.

	As % of DM[a]					Sheep or goats[b]			
	CP	Ash	EE	CF	NFF	PD (%)	TDN (%)	DE (Mcal/kg)	ME (Mcal/kg)
Rice straw	3.7-4.2	15.2-22.8	0.9-1.7	27.5-35.9	31.4-41.3	0.1	41	1.80	1.37
Maize stover	5.1-7.9	7.5-8.8	1.6-1.7	27.6-36.8	46.9-55.3	2.1-4.6	44-59	2.25-2.64	1.82-2.87
Sorghum stover	3.5-11.2	3.9-9.5	1.4-2.1	30.9-38.1	43.9-56.0	1.0-9.5	31-48	2.12	1.70
Sugarcane tops	2.7-6.4	5.3-7.6	0.8-1.7	28.4-35.0	50.4-43.8	1.7	42	-	-
Peanut hay	8.1-19.9	8.7-12.3	1.5-4.8	26.9-40.6	30.9-45.0	9.7-11.5	54-65	2.37	1.94
Soybean hay	4.2-16.6	6.1-9.4	0.9-6.2	28.8-38.5	39.0-50.2	-11.5	-56	2.46	2.04
Cowpea hay	14.4	9.9	2.3	22.3	51.0	9.5	59	2.62	2.19
Mungbean hay	9.2	11.3	1.5	38.1	39.7	-	-	-	-
Sweet potato hay	13-20	9.5-17.4	2.2-3.4	15.3-20	44.2-55.3	9.1-15	68	-	-
Cassava leaves	15.6-23.4	6.0-10.8	2.9-6.3	8.1-26.1	35.2-60.4	12.4-20	47-67	2.95	2.53
Millet	3.1-6.9	6.8-10.9	1.2-1.5	31.8-40.4	48.5-48.9	-	54-59	-	-

Source: Preston (1977), Devendra (1979, 1981), Gerpacio and Castillo (1979), Hari Hartadi et al. (1980), Anon. (1984), and Soedomo et al. (1984).

[a] DM, dry matter; CP, crude protein; EE, ether extract; CF, crude fibre; NDF, neutral-detergent fibre.

[b] PD, protein digestibility; TDN, total digestible nutrients; DE, digestible energy; ME, metabolic energy; 1 cal = 4.1868 J.

off side branches as a form of crop thinning. These cuttings can be fed to small ruminants and would provide a high-quality feed for supplementing poorer quality residues.

Peanuts (*Arachis hypogaea*)

Peanuts (groundnuts) are widely grown throughout the region and, on the basis of area harvested, peanuts are the fifth most important annual crop in the region. Yields of peanuts average 1200 kg/ha. The ratio of residue yield to nuts is, however, highly variable. Gerona et al. (1985) found a variation of this ratio from 0.9 to 2.9, depending on climatic conditions, with other values recorded in the literature that is also highly variable (Table 5). Residues can be fed fresh or as hay in the dry season.

Cassava (*Manihot esculenta*)

Cassava is widely grown in South and Southeast Asia (Table 3). The average yield of tubers is 10,200 kg/ha. On a DM basis, leaves are only 6 or 7% of the total biomass and 7-12% of the fresh weight of tubers giving average leaf yields at harvest of 700-1200 kg/ha. Throughout the growth cycle, however, total leaf production is much higher as leaf abscission is continuous throughout the growth cycle. Wide variation in the nutritive value and chemical composition has been recorded (Table 5). Although the crude protein (CP) is generally high, cassava leaf protein is deficient in methionine, and the biological value of cassava leaf protein is increased considerably by supplementation with methionine (Eggum 1970). Cassava leaves can also contain high levels of HCN, but there is considerable variation between varieties and wilting or drying decreases HCN concentrations to acceptable levels for feeding to ruminant animals. Because of its high protein content, cassava leaves provide a useful fresh supplement to other crop residues.

Sugarcane (*Saccharum officinarum*)

Sugarcane is grown in all countries of South and Southeast Asia. Mean yields in the region are 43,800 kg/ha fresh weight with considerable variation in yield between countries. The yield of sugarcane tops varies from 18 to 30% of the total fresh yield where the cane is not burnt before harvest. Although sugarcane tops and leaves are very low in protein, they are readily eaten by ruminant animals and provide a good energy supplement. For high animal growth rates, however, there is a need for both additional bypass protein and glucose precursors (principally starch) (Preston 1977).

Sweet potato (Ipomaea batatas)

Sweet potato is quite widely grown in the region with the largest harvested areas occurring in Vietnam, Indonesia, India, and the Philippines (Table 3). The average fresh yield of tubers is 9100 kg/ha, with a wide variation between countries (Table 4). Gerona et al. (1985) found that root yields varied from 1.5 to 4.6 t DM/ha, with the sweet potato tops giving a similar range of yield; 65% of sweet potato vines are stem and 35% are leaf. The CP content and digestibility of vines are high (Table 5). Gerona et al. (1985) also point out that up to 40% of root DM yield is not marketable because tubers are too small. These can also be used to supply a high-energy, low-protein diet for ruminant animals.

Other minor crops

Residues of other minor crops are also available in the region for ruminant feeding. Crop residues of leguminous crops such as mungbeans (Phaseolus mungo), cowpeas (Vigna unguiculata), pigeon pea (Cjanus cajan), rice bean (Phaseolus calcaratus), and winged bean (Psophocarpus tetragonolobus) can provide valuable sources of forage. Hay made from these crops has a similar chemical and nutritive value to peanut hay.

Bananas are another source of feed for small ruminants and yield 83% pseudostems and 5% leaves. Although CP is low (0.1%), they are highly digestible (75% dry matter digestibility (DMD)) and can provide a valuable ration component or a succulent dry-season feed.

Natural (Native) Forage Resources

Farms on which annual cropping is the major enterprise usually have small areas of land that are not used for cropping. The native grasses, herbaceous legumes, and other broad-leaved herbs that grow on these areas provide a valuable feed resource for ruminant livestock. These resources are utilized by cut and carry systems to feed penned or tethered animals or supervised free grazing.

The total quantity of feed available per farm from these resouces depends on the area available and the average yield. Yields are highly variable depending on species composition, climatic conditions, soil fertility, and cutting or grazing management. Chee and Wong (1985) found in Malaysia that the yields of native pasture from rice bunds, fallow fields, and roadsides was 7 t/ha per year. In Malaysia, feed from fallow fields contributed 28% of the total feed supply (Chee and Wong

1985), whereas in three areas in Indonesia, native grasses provided 62-94%, herbs 2-11%, shrubs and tree leaves 1-15%, and crop residues 2-21% of the feed for small ruminants (van Eys et al. 1984).

The quality of native forages is also highly variable depending on species composition, soil fertility, and seasonal conditions. The nutritive value of feeds is usually highest early in the wet season with decreasing nutritive value late in the wet season with a further decline in the subsequent dry season. Unless the legume composition is high, these forages would generally only provide a maintenance diet for small ruminants for most of the year. Six-week-old roadside grasses fed to sheep in Indonesia, which contained 6.6% CP and 71.3% neutral-detergent fibre (NDF), were found to have a DMD of 52% and metabolizeable energy of 7.5 MJ/kg (Mahyuddin 1983). In Malaysia, the nutritive value of native herbage consumed by sheep was comparatively high, but variable, with a CP content of 6.7-11.4% (Chee and Wong 1985). When the mineral composition of native grasses fed to small ruminants in Indonesia was monitored over a 1-year period, it was found that phosphorus and copper deficiency levels were indicated in 70 and 26% of samples, respectively, with a few samples being deficient in copper and zinc (Prabowo, Mathius, van Eys et al. 1984). The inclusion of salt and minerals to a grass diet increased the intake and digestibility of the feed (Prabowo, Mathius, Rangkuti et al. 1984).

Introduced Sown Forages

The introduction of selected grasses, herbaceous legumes, and tree legumes as additional sources of higher quality feed has occurred throughout the region. These are sown on small areas of land in fields and around houses, in hedgerows in the case of tree legumes, or are combined in the cropping program in various ways. Forage legumes particularly can be introduced into the cropping pattern as rotational crops, relay crops, intercrops, or alley forage crops, with the aim of increasing the fertility of the soil and crop yield and improving the feeding value of the crop residues.

Grasses

Introduced grasses have been selected for higher yield and leaf production compared with native grasses; however, they require fertilizer inputs, particularly nitrogen, to provide high yields of high nutritive value. In Malaysia, a range of introduced grasses yielded up to 30 t/ha per year (Wong 1980), with a range of CP content of 9.6-12.9% and DMD of 50.8-64.1% (Chee and Wong 1985). In Thailand, yields of grasses grown around farm houses have been up to 16 t/ha for guinea grass (Topark-Ngarm and Gutteridge 1985) and, in Indonesia, a range of grasses subjected to various heights and frequencies of cutting have yielded up to 38 t/ha per year with a range of CP content of 6.2-11.9% (Siregar 1985).

Herbaceous legumes

Selected herbaceous legumes have been introduced and grown in most countries of the region. Their yield potential is not as high as from grasses, but their nutritive value is much higher (Devendra 1979). In northeast Thailand, there has been considerable research on the introduction and utilization of herbaceous legumes in dryland cropping systems. *Stylosanthes* species have been used for sowing on bunds of rice fields during the crop season. Yields obtained have been 3.9 t/ha for *S. hamata*, 5.1 t/ha for *S. scabra*, and 2.5 t/ha for *S. humilis* (Gutteridge 1981). Higher yields have been obtained by *S. humilis* (7200 kg/ha) and *S. hamata* (9800 kg/ha) in swards (Topark-Ngarm and Gutteridge 1985).

Herbaceous legumes have also been used to provide a quick source of high-quality feed after a rice crop. Shelton (1980) found that *Crotalaria juncea* yielded 1600 kg/ha when grown after a rice crop at the end of the wet season. Gibson (1984) has also used *Macroptilium atropurpureum* and *S. hamata* as ley pastures in upland monocropping systems. Besides providing valuable feed when fertilized with phosphorus and sulfur, the yields of subsequent crops of kenaf and cassava were doubled. Other quick-growing, high-yielding species are also available for use as relay or ley forages, such as *Lablab purpureus*, *Vigna unguiculata*, and *Vigna vexillata*.

In Indonesia, legumes have been grown with and without grasses on the vertical face (riser) of terraces in upland cropping-livestock systems. Yields of 6 and 10 t/ha per year have been obtained for *Centrosema pubescens* and *Stylosanthes guianensis*, respectively (Siregar et al. 1985). Much lower yields of legume were obtained in mixtures with grasses.

Tree legumes

In recent years, there has been a growing awareness of the general multipurpose value of tree legumes and their specific multipurpose value in cropping-livestock systems. Brewbaker (1985) has provided detailed information of 25 tree legumes that can be used for fodder for livestock in Southeast Asia.

Among these species, leucaena (*Leucaena leucocephala*) has been the most widely planted and utilized for livestock feeding. With the emergence of the psyllid (*Heteropsylla* species) insect as a major pest on leucaena in the region, however, there is considerable doubt on the importance and usefulness of leucaena in the future. Other tree species that are used widely for animal feeding in the region include *Gliricidia sepium*, *Sesbania grandiflora*, *Sesbania sesban*, *Erythrina* spp., and *Acacia* spp. (Devendra 1984; Manidool 1984).

The effects of cutting management and plant density on yield of leucaena have been reviewed by Horne et al. (1985). Yields of leaf have been recorded as high as 15 t/ha per year. Similar leaf yields can be obtained by other tree species. In Indonesia, maximum leaf yields of 10.7, 12.1, and 12.1 t/ha were recorded over an 8-month period for *Calliandra calothyrsus*, *G. sepium*, and *L. leucocephala*, respectively (Horne et al. 1985). Yields from *S. grandiflora* were lower because of its inability to give high yields with repeated cutting.

Brewbaker (1985) has also summarized the forage quality of 25 tree legume species. Generally, CP contents of all species are high (18.1%), although a range of values from 7 to 35% is given. Fibre contents are also highly variable (8-48%), with an average value of 21.4%.

Production systems for tree legumes usually consist of either a dense planting of trees (more than 40,000 trees/ha) in a small area or rows of trees planted as a hedgerow on bunds, as edges of crop areas, or interplanted with crops (alley cropping). Leaf production seems relatively unaffected by frequency of cutting, although wood production is increased with decreasing cutting frequency (Horne et al. 1985). *Sesbania grandiflora* (sesbania) is not suited to frequent defoliation. In Java, sesbania is planted in the wet season as an annual forage crop in rows on the rice bunds, and then leaves and branches are gradually removed during the dry season with the residual wood used for fuel.

The leaves of tree legumes can be used as a high-quality supplement to crop residues for small ruminants. Many feeding experiments have shown higher live weight gains by sheep and goats from the inclusion of a proportion (up to 20-25%) of tree legume leaves with crop residues or grasses (Armiadi Semali and Mathius 1984; Rangkuti et al. 1984).

INTEGRATED ANNUAL CROP AND SMALL RUMINANT PRODUCTION

In general, small ruminant production is a very small or insignificant component of total livestock production in many countries in the region, particularly in annual cropping systems where ownership of large ruminants is preferred because of the need for draft power. In most countries, small ruminant production is not a planned integral component of annual cropping systems and is often associated with landless people who opportunistically utilize forage resources on public lands to feed penned animals in the backyards of houses. In many situations, however, there is scope for small ruminant production where farm size is already too small to warrant the ownership of a large ruminant or where farm size is greater than that needed to provide feed for one or two large ruminants.

The challenge in integrating small ruminant production with annual cropping systems is to utilize the mutual benefits of crops and livestock to provide greater income to farmers with minimal disruption to their traditional crop production system. The difficulty in attempting to review small ruminant production in annual cropping systems is the lack of quantitative data in the region on the utilization of feed resources and animal production in such systems and the diversity that exists in cropping patterns. For example, Zandstra (1977) was able to compare the productivity and net returns of 10 possible cropping patterns in just one rain-fed, bunded, rice-growing area in the Philippines. Integrating livestock production with each cropping pattern would require different feeding strategies. In general terms, consideration can be given to the possibilities and potential for small ruminant production in three general annual crop production systems: irrigated rice, rain-fed rice - dryland cropping, and dryland cropping - mixed gardens.

Irrigated Rice System

Multiple monocropping of irrigated rice is the most intensive annual crop production system in the region. Such a system does not allow the utilization of the cropland for forage production and produces large amounts of rice straw at certain times of the year. This severely limits the opportunities for integrating small ruminant production. Small ruminant production would have to depend on treatment and storage of rice straw and the use of rice bran and forage supplements. In irrigated rice systems in Indonesia, however, small ruminant production does not depend to any extent on crop residues, but rather on the availability of forage from noncrop areas. Native grasses provide a basal supply of forage with higher quality supplements required from leguminous and nonleguminous trees grown around the edges of cropland or around houses.

Rain-fed Rice - Dryland Cropping System

The major food crops grown in this system include rice, maize, millets, sorghu, cassava, and leguminous crops such as soybean, peanut, cowpea, pigeon pea, and mungbean. Rice, maize, sorghum, and cassava are usually grown as main crops during the middle of the wet season with the leguminous crops preceding or following the main crop.

Greater opportunity exists for combining small ruminant production in such systems because of the wider diversity of feed available and the opportunity to regulate their availability throughout the year. Leguminous crops and forages can be used as leys, relay crops, intercrops, or alley crops to supplement the quality of the graminaceous crop residues. In addition, there is opportunity for farmers to grow different crops concurrently to provide a better mix of crop residues for ruminant feeding. Fresh native pasture, however, seems to provide the basic source of feed throughout the year, as illustrated by Moog (1985) for cattle in a rice-corn cropping system in the Philippines, by van Eys et al. (1984) for sheep and goats in rice monoculture and multiple cropping systems in Indonesia, and by Bhasayavan et al. (1985) for cattle in rice-corn-cassava-peanut mixed cropping system in northeast Thailand. In a lowland rice monoculture cropping system in West Java, van Eys et al. (1984) found that rice residues were an insignificant component of the diets for goats and sheep and that a range of crop residues only contributed 5-16% of the total diet compared with a 62-80% contribution from grasses. They also found that more grasses and less weeds and crop residues were fed to sheep than goats. In an upland multiple cropping system, grass was also the most important component of the diet of sheep (65-75%), with crop residues only a minor component. In another upland multiple crop system, Petheram (1986) also found that grass was 47-60% of the diet of goats, but that crop residues, mainly cassava, sweet potato, and maize tops, were a large component (35-43%). It is interesting to note that, in the same cropping system, buffalo were fed 45% grass but 55% of their diet was fresh and dry rice straw.

Supplementary feeds in these systems should be of high quality. Opportunities also exist for utilizing part of the crops for green forage during their life cycle through practices that do not significantly reduce crop yield, such as high-density sowing followed by thinning, leaf stripping, and topping of maize. The planting of special-purpose forages on small areas, such as highly fertilized grass, herbaceous legumes, or tree legumes, also provide opportunities to supplement the various crop residues and overcome quantitative or qualitative shortages.

Dryland Cropping - Mixed Garden System

In regions that are too dry for rice culture, feed shortages will be most apparent during the dry season. The same opportunities exist for utilizing and integrating various crop residues, but more emphasis has to be given to conserving residues as hay or silage and providing feed from other sources during the dry season. Usually, there are larger areas of native pasture available in these cropping systems and in addition forage is also available from vegetable and tree crops. In these systems, more emphasis should be placed on tree legumes to provide high-quality feed in the dry season and the storage of leguminous crop residues. The planting of forage legumes as a relay crop can improve the quality of crop residues for grazing following crop harvest.

CONCLUSION

Ruminant animals provide a minor source of farm income in annual crop systems. Priority is given by farmers to large ruminants because of their important contribution to draft power. On a regional basis, small ruminants are generally not important in annual cropping systems. Considerable potential exists, however, for their integration with annual cropping systems. The success of such small ruminant cropping systems will depend on developing suitable feeding systems throughout the year that complement the cropping systems and demonstrate clear economic and social advantages. There is much information available on the quantity and quality of various feed sources in cropping systems and productivity gains from various feed combinations given to small ruminants in controlled feeding experiments. There is a widespread lack of information, however, on the actual utilization of feed resources by small ruminants in existing cropping systems and the response to various interventions or changes to feed sources on animal production, crop production, or socioeconomic benefits. It is time that research was taken to the actual farm systems. Because of the wide range of cropping systems practiced and the site specificity of the crop-livestock system, there is a need for integrated farming systems research throughout the region to develop strategies and systems to maximize the utilization of the various forage options.

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PRODUCTION SYSTEMS BASED ON TREE CROPPING

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Abstract *Fodder shrubs and trees are still integral parts of smallholder farming systems in South and Southeast Asia, because, apart from supplying feeds, they meet the technical economical, social, and cultural needs of the smallholder farmers. With the wide variety of fodder shrubs and trees available, and with the many types of tree-cropping systems, various production systems based on tree cropping are invariably found on smallholder farms.*

Smallholder farmers in dryland farming areas are more dependent on production systems based on tree cropping than are those in rice farming areas. With diversification from annual crop to perennial crop production, the role of fodder shrubs and trees becomes more important. Research on the integration of fodder shrubs and trees in smallholder farming systems should put more emphasis on cropping systems to increase the yield, quality, and utilization of the fodder to maximize the livestock production without upsetting the ecological balance of the area.

Of the 435 x 10^6 ha that make up Southeast Asia, 78% is agricultural land (55% forest, 14% arable land, 5% permanent pasture, 4% permanent crops) (FAO 1983). With 60 x 10^6 ruminants, the carrying capacity of the agricultural land is 0.6 ruminants/ha.

In the integrated small-scale farming system, fodder shrubs and trees are always found on the farms. With the average population of 230 fodder shrubs and trees per hectare and with the average annual tree fodder yield of 7 kg dry matter (DM)/tree (Nitis et al. 1980), the agricultural land could produce 152 x 10^6 t DM of shrub and tree fodders. With the average shrub and tree fodder supplement of 18% of the total feed consumed by ruminants (FAO 1985), shrub and tree fodder could supplement 155 x 10^6 animal units (AU) (500 kg each) in this region. Furthermore, fodder shrubs and trees could supply other commodities such as firewood, timber, and wood for farm implements.

PRODUCTION SYSTEMS

Because smallholder farmers usually grow shrubs and trees that could be used for livestock feeds, firewood, farm implements, and other activities in the farms, it is difficult to identify a specific production system. Based on primary and secondary purposes, however, some production systems can be identified and include those for fodder, wood, fruit, and green manure. For example, in the integrated smallholder farming systems, ruminant feeds always contain a certain amount of shrub and tree fodder. In this area, farmers prefer to grow fodder shrubs and trees than grass, because such fodder can be conserved in situ. With proper lopping (cutting according to requirements) management, shrub and tree fodders can be available year-round.

In many rural areas, 80% of the energy used is in the form of wood (Blain 1985). Firewood, which is usually not specially grown, may be in the form of shrubs and small tree branches, so that it can be used easily for household cooking.

For certain home industries, farmers grow specific shrubs and trees for firewood. For large-scale industrial uses, fuelwood trees are usually grown in plantations. The most commonly used species are Caliandra eryophila, Gliricidia sepium, and Erythrina variagata, with annual wood production ranging from 8 to 50 m^3/ha, calorific value from 4,200 to 24,900 kcal/kg, and specific gravity from 0.42 to 0.78 (NAS 1980; IDRC 1983).

Farmers also grow trees such as Lannea corromandilica, Ficus poacellii, Hibiscus tilliaceus, Artocarpus integra (jackfruit), Manggefera indica (mango), Cocus nucifera (coconut), and Azadirachta indica for timber production. To produce reasonably good timber requires at least 30 years, and, for lumber production, trees must meet the trade specifications.

The most common fruit trees grown on the farms are jackfruit, mango, banana (Musa paradiciaca), and pao-pao

(*Carica papaya*). Oil-producing fruit trees, such as coconut, are always found on farms at elevations up to 600 m. Oil palm (*Elaeis guinensis*), however, is not usually grown on the smallholder farms. Kapok (*Cariba pentandra*) fruit is used for stuffing and insulation, whereas tamarind (*Tamarindus indica*) fruit is used as an ingredient for cooking and medicine.

Shrubs, such as *Caliandra*, *Codariocalyx*, *Fleminga*, *Leucaena*, and *Sesbania*, are grown in the field for use as green manure. In some areas in the eastern part of Indonesia, the traditional practice is to break the branches and leave them hanging on the trees until all the leaves wither and fall gradually among the emerging cash crops (Parera 1982). Another successful practice with *Leucaena* is to make a girdle (ring barking) so that within 1 month the leaves will dry and fall (Pressner 1982), and then these *Leucaena* plants, with double-row spacing, can produce 5-10 t/ha of fresh leaves for use as green manures.

Under traditional farming practices, although the green manure provided by pruning the shrubs and trees is beneficial, it is not sufficient to maintain soil fertility. Furthermore, utilization of shrub and tree fodder by ruminants and the use of its manure as fertilizer is a more efficient utilization of the carbon and nitrogen in the plant than directly using it as a green manure.

Trees such as *Ficus*, *Lannea*, *Hibiscus*, *Azadirachta*, and *Zizynkus* are used as shade for ruminants tethered or grazing in the field. Shrubs, such as *Leucaena* and *Gliricidia* and trees, such as *Erythrina*, are used as shade for the young coffee, cocoa, and clove plants. In Malaysia, *Leucaena* is often used as nurse crop for teak and the Araucaria species (Ng et al. 1982).

In the vanilla plantations, *Leucaena* and *Gliricidia* are used as climbers, whereas, in the pepper plantations, *Erythrina* variagata is used. In the critical (i.e., greater than 10° slope) and sloping lands, pioneer shrubs, such as *Leucaena*, *Gliricidia*, and *Caliandra*, are planted to prevent soil and wind erosion. In the eastern part of Indonesia, farmers found earthworms after the 1st year of establishment of *Leucaena* (Parera 1982).

Flowers of the *Machellia champaca* and *Caecalpinia pukte* and leaves of the *Ficus religiosa* are used for religious ceremonies. Leaves of the *Moringa oleifera* can be used as an ingredient in traditional medicine. *Sesbania* bark can be used as a source of tannin; *Lannea* bark, as a source of glue.

TREE CROPPING SYSTEMS

Intercropping

In the intercropping system, shrubs and trees are grown along with cash crops. In the form of windrows (e.g., nurse trees in timber crops), between cash crop plants (shade trees in the coffee plants, with the cash crop plant (e.g., climber trees for vanilla), or scattered among the cash crop plants (e.g., *Sesbania grandiflora* in the corn and cassava cash crop). The shrubs and trees are lopped periodically to prevent their shading the cash crops. For the timber crop, lopping is not necessary, because the timber plant will grow over the nurse trees.

Embankment

In the wetland farming areas in Indonesia, some farmers grow shrubs, but not trees, on the wall/bund of embankment fields. *Sesbania grandiflora* is the shrub most commonly grown on the bund of rice fields. On the bund of dryland farming areas in the coastal area, banana, coconut, jackfruit, and mango are common, whereas on the bund of dryland farming areas in the higher altitudes (above 500 m), *Erythrina variagata*, *Caliandra*, and *Flagellaria indica* are common.

On the critical and sloping lands, shrubs and trees are grown in rows to form a terrace. Experiments in the Philippines showed that planting *Leucaena* in double hedgerows across the slope will cause the formation of natural terraces across the slope after 3 years of continuous cultivation (Pacardo 1985).

Along the roadside and surrounding the public field, shrubs such as *Leucaena* and *Gliricidia* and *Tamarindus*, *Lannea*, and *Albezia* trees are grown. Shrubs and trees (e.g., banana, bamboo, sago palm, and *Erythrina lethosperma*) are also grown on the bank of water catchments, creeks, rivers, and other waterways.

Cluster

Shrub and tree clusters are usually found in areas not suited for cash crop production. The number of plants per cluster varies from 10 to 50. One tree cluster consists of four trees used, for example, as poles for livestock stables and poles for bird-watching huts in the field. Any shrub or tree can form a cluster. For the post of the livestock stall and birdwatching hut, Lannea, Erythrina, and Hibiscus are most commonly used.

Hedgerow

Farmers usually use live fences to mark land boundaries, livestock yards, etc. First, the soil is tilled and then seeds are planted in a windrow at 2 cm depth. When cuttings are planted, the length is 0.5-1.5 m for the shrubs planted at 10 cm spacing and 1.5-2.0 cm length for the trees planted at 25 cm spacing. Seeds are planted during the rainy season, whereas cuttings are planted at the onset of the rainy season. Branches are lopped regularly, but the trunks are cut occasionally at 10-20 m height.

Backyard

Many shrubs and trees are grown in the backyards of the farmhouses and in the backyards of the houses in the village. In most Indonesian villages, shrubs and trees are grown in the house compound as part of the "Karang Kitri" (growing shrubs and trees for traditional medicines, vegetables, and other household requirements) program launched by the government. In most backyards of Balinese houses in the villages, there are 3-10 Pissonia alba trees because the leaves are used as a feed supplement for the pigs that are also kept in the backyard.

Forest

Tree cropping systems for lumber and pulpwood have their own characteristics. Forestry departments in most of Southeast Asia are concerned about the indiscriminate cutting of valuable timber for firewood and fodder. For this reason, many systems have been developed (e.g., nurse trees, ring system) to manage the forest for lumber and pulpwood with the accompanying shrubs and trees for firewood and livestock feeds.

Savannah

In the extensive farming system, shrubs and trees grow singly or in a cluster among the natural grass. When not enough grass is available, ruminants browse the tree leaves and, by the end of the dry season, it is not uncommon to find that the whole diet consists of tree leaves exclusively. Because ruminants browse as high up as they can reach, gradually an umbrella-like canopy is formed.

TREE FODDER AVAILABILITY

Variety of Fodder Trees

The type of shrubs and trees used as fodder by smallholder farmers varies from region to region. In Nepal, there are 132 fodder shrubs and trees (Panday 1982); in India, 45 fodder trees and browses (Ranjhan 1985); and, in Africa, about 75% of the shrubs and trees serve as browses for the livestock (Sherman 1977). In Bali, Indonesia, 55 fodder shrubs and trees are used during the dry season (Nitis et al. 1980). Of these, only 13% are legumes; the other 87% are nonleguminous species.

In the wetland farming system in Bali, there are 26 fodder shrubs and 31 fodder trees that grow around the walls of a 1 ha field; whereas, in the dryland farming system, there are 104 fodder shrubs and 304 fodder trees (Nitis et al. 1980). In some intensive dryland farming areas, many farmers shift from annual crop (corn, cassava, and peanut) to perennial crop production (vanilla, clove, and coffee) (Nitis, Lana, Tjatera et al. 1985). In this area, many more shrubs and trees are grown to support this system.

Ruminant Feed Composition

Generally, the leaves and small branches are used as fodder. For bananas, the pseudostem is for large ruminants and pigs, whereas the corm (underground stem) is for cattle. For sago palm (Arenga pinnata), the young fruit is for cattle and the inner part of the trunk is for ducks and cattle. Coconut oil meal and palm oil meal (by-products of oil-extraction processings) are rich protein concentrates for ruminants and nonruminants alike.

The use of shrubs and trees as animal feeds probably goes back as far as when animals were first domesticated, considering that Caratonia siligua (a nonlegume) and Prosopis cineragia (a legume) have been recorded as being used for fodder for more than two thousand years (Robinson 1984). Forage fed to cattle and buffalo in the intensive smallholder farming system in Bali contains 5-15% shrub and tree leaves, whereas those fed to goats contain 61% (Nitis et al. 1980) (Table 1). During the dry season, the proportion of the shrub and tree leaves increases. Also, the type of shrub and tree leaves fed to goats is not only affected by climatic zone and topography, but also by land utilization and soil surface condition (Nitis et al. 1980).

Even though smallholder farmers have been incorporating shrub and tree leaves into their ruminant feeds, experimental data on the response/acceptance of the ruminants are not easily accessible. Sheep fed Pennisetum purpureum supplemented with 0.5-2.0 kg of Sesbania glandiflora leaves gained 2.7-5.0 times more weight than those without supplementation (Mathius and van Eys 1983). Gliricidia as the sole diet could maintain sheep and goats through the dry season without ill effects to the health of the animals (Carew 1983). Voluntary intake of goats fed changing ratios of grass to Leucaena is greater than that for sheep; and the highest intake is from a diet containing 75% Leucaena and 25% grass (Devendra 1984).

Yearling and 2-year-old cattle grazing Heteropogon contortus supplemented with Leucaena (on a ratio of 1 ha of Leucaena to 3 ha of native pasture) gained 94% more weight and had better carcass quality than the unsupplemented cattle (Foster and Blight 1983). Feedlot trials showed that heifers fed 50% rice straw supplemented with 40% Leucaena plus 10% concentrate gained 34.6% more weight than those fed with rice

Table 1. Botanical composition (%) of the forage fed to livestock in Bali, Indonesia.

Forage species	Livestock species		
	Cattle	Buffalo	Goats
Grasses	78	87	37
Legumes	3	5	2
Shrubs and trees	15	1	61
Straw	2	2	-
Stems	1	1	-
Others	1	3	1

Source: Nitis et al. (1980).

straw and Leucaena plus rice bran had a weight gain of 700-800 g/day, whereas those fed ordinary roughage only gained 200-300 g/day (Aquino 1983). Bali cattle fed 80% natural grass supplemented with 9% shrubs (Leucaena and Musa) and 11% tree leaves (Erythrina and Artocarpus) gained 58% more weight than those cattle fed without shrub and tree-leaf supplements (Nitis and Lana 1984). In general, the shrub and tree fodder supplements increased livestock performance.

TREE FODDER YIELD AND QUALITY

Yield

Potential yield is the estimated amount of shrub and tree leaves available when complete defoliation is carried out, whereas lopping yield is the amount of fodder available through strategic and systematic defoliation. Lopping yield varies from species to species and from season to season. In Bali, lopping yield of Caliandra eryophila is 0.34, whereas lopping yield of Ficus poacellii is 20.23 kg DM/tree per season (Nitis, Lana, Susila et al. 1985). Lopping yield for each tree during the dry season is usually lower than what is gained during the wet season, because during the dry season more shrub and tree species are lopped to meet forage requirements. With such a system, farmers have indirectly minimized the physiological and nutritional constraints to the plant.

Chemical Composition

The chemical composition of shrub and tree fodder in Malaysia (Devendra 1979), the Philippines (Gerfacio and Castillo 1979), Nepal (Panday 1982), India (Ranjhan 1985), and Indonesia (Nitis, Lana, Susila et al. 1985) has been reported in the literature. In general, the crude protein (CP) content of the shrub and tree leaves is higher than the natural grass (Nitis, Lana, Susila et al. 1985).

Topography, land utilization, soil surface condition, climatic zone, and season have been shown to exert some effects on the chemical composition of the shrub and tree fodders (Nitis, Lana, Susila et al. 1985). Sesbania glandiflora leaves in the rice field contain 21% more CP than those in the dryland farming area. Hibiscus tiliaceus leaves in the rice field, however, contain 12% less CP than those in the dryland farming area.

Digestibility

Nutrient digestibilities of some shrub and tree fodders vary according to species and growth (Bo Gohl 1975; Kearl 1982). Topography, land utilization, soil condition, climatic zone, and season have also been shown to affect the DM digestibility of some shrub and tree fodders (Saputra 1982). The in vitro DM digestibility of Hibiscus leaves in the rice field is 5-7% higher than those in dryland farming area during the wet and dry seasons (Table 2). For Sesbania leaves, the in vitro DM digestibility is the same for the rice field and dryland farming area during the wet season, whereas, during the dry season, the in vitro DM digestibility in the dryland farming area is slightly higher. In vitro DM digestibility of Sesbania (legume) is 63% higher than that of the Hibiscus leaf (nonlegume).

Specific Substance

Specific properties, such as the presence of mimosine in Leucaena leaf, latex in Ficus leaf, tannin in Lannea leaf, and astringent odour in Gliricidia leaf, may reduce the quality of the above-mentioned fodders. Some smallholder farmers in Bali claim that H. tilliaceus leaf could prevent constipation in goats and cattle; the young Borrasus flabellifer fruit could act as a deworming agent in cattle. It has also been claimed that the inner part of the coconut leaf sheath and the inner part of the Arenga trunk when fed to cattle will increase the ability of the cattle to plow the field.

TREE FODDER MANAGEMENT

Some shrubs (such as Gliricidia) and trees (such as Lannea) shed their leaves during the dry season (the time when green feed is required for livestock feeding). Farmers overcome this drawback by lopping shrubs and trees 2-3 months before the onset of the dry season. The new shoot will grow and produce young and succulent green feeds during the dry season.

To prevent overdefoliation, farmers will lop the lowest branch first, followed consecutively with the upper branches. Lopping ends when two-thirds of the canopy has been cut. By this time, new bud primordia have developed on the lower branches. After full emergence, the lopping begins again on the remaining one-third of the canopy.

Table 2. Effect of land classification on the in vitro dry matter digestibility (%) of Hibiscus tilliaceus leaves.

Land classification	Wet season	Dry season
Topography		
Low-lying area	45.83	45.95
Hill	42.56	41.37
Higher altitude	40.76	40.32
Land utilization		
Rice field	40.43	39.66
Dryland farming area	38.34	37.04
Plantation	42.66	38.39
Climatic zone[a]		
B (9/3)	42.60	42.03
C (7/5)	40.28	38.36
D (6/6)	44.98	42.13
E (5/7)	47.85	47.28
F (4/8)	38.85	38.87
Average	41.95 ± 2.91	40.92 ± 3.01

Source: Saputra (1982).

[a] Values in parentheses represent the number of wet/number of dry months.

Fresh Gliricidia leaves produce an astringent odour that discourages some livestock from eating these leaves. Most farmers overcome this by cutting the Gliricidia branch in the morning and letting the leaves wilt during the day; the livestock will eat the leaves in the afternoon.

For individual feeding, farmers will select specific shrubs and trees for the different classes of livestock production. When group feeding is practiced, however, such methods cannot be implemented. Under tethering conditions, younger animals will browse the lower canopy and older animals will browse the upper canopy. Under stall feeding, as with goats, farmers will hang the lopped branches upside down. With such a method, the young goat will eat the younger leaves hanging close to the ground, whereas the larger goat will eat the older leaves higher up.

Most, if not all, smallholder farmers recognize the importance of fodder shrubs and trees in reducing their cash expenses. A case study carried out in a dryland farming area in Bali showed that a farmer could save up to IDR 523,000/ha per year (in 1986, 1,625 Indonesian rupiah (IDR) = 1 United States dollar (USD)) in the form of livestock feed (IDR 193,000), firewood (IDR 104,000), fruit (IDR 218,000), and farm implements (IDR 8,000) (Nitis 1985).

CONSTRAINTS

In smallholder farming systems, there are no major problems in integrating shrubs, trees, and livestock with the annual crops; however, the same problems do merit special attention. For example, in smallholder farming systems, annual crop production is the main activity, whereas perennial crop production is a sideline; therefore, production based on tree cropping is not as important as that based on annual cropping, particularly in the wetland farming area. Farmers who own their own farms will manage the shrubs and trees according to its production needs. In the communal land or land not managed for annual crop production, shrubs and trees may be cut indiscriminately by the landless farmer who keeps livestock as a backyard activity. The housewives may do the same, not for livestock feeds, but for firewood.

In the intensive smallholder farming system, no land is especially allocated to grow grass. Growing fodder shrubs and trees is usually confined to land not suitable for crop production. For backyard livestock holders, where land availability has become a problem, they claim the land along the road and in public places by cutting the fodder shrubs and trees grown in these areas. It is not uncommon for landless livestock holders to agree among themselves to put "unseen boundaries" on land that does not actually belong to them.

On the plantation or in the forest, most livestock is fed grass grown in these areas. During the dry season, however, or when the plantation and the forest become older, not enough grass is available for the livestock. Workers start cutting the shrubs and branches of the trees not only for livestock feed but also for firewood, without consulting the plantation owner or the forest officers.

In Indonesia, government officials, private enterprise, and social organizations are actively donating livestock to successful farmers or organizations in the village, but this is often not preceded by planting extra fodder shrubs and trees to support them so that the carrying capacity of the land may be affected.

Until 1977, in the state of Bihar, India, relations between the villages and the forestry officers were extremely poor. A volunteer from a nongovernmental organization was invited to act as a mediator and, by 1982, enough cooperation and communication developed between the two groups that a survival rate of 75-80% for young trees was achieved (Blain 1985).

Customs and Traditions

In some villages in Indonesia, farmers prefer to keep cattle instead of goats because cattle bite with their tongues so that the bud is not eaten, whereas goats bite using the dental pad thereby eating the entire bud. Furthermore, most farmers still consider grass as being better than shrub and tree fodder, despite the fact that the latter usually contains more protein. When cattle and goats are kept on one farm, farmers will give the grass to the cattle and the fodder shrubs and trees to the goats because cattle are considered to be a better class of animal than goats.

In most traditional farming systems in Indonesia, integration between crop and livestock is bound by conventional laws where the crop is given more priority than cattle so that when livestock eat the cash crop, the owner of the livestock will be fined. In some places in the eastern part of Indonesia, however, the opposite is true, in that farmers prefer to raise livestock over growing fodder shrubs and trees.

Some ethnic groups in Africa are reluctant to keep shrubs and trees because of the spirits they believe inhabit the forest (Blain 1985). Furthermore, some African farmers consider shrubs and trees as hiding places for insects and birds that ravage their crops.

RESEARCH RESULTS

Much research has been carried out on fodder shrubs and trees. The following are perhaps some of the most important results for production systems based on tree cropping.

- ° Alley cropping involves growing cash crops between rows of frequently pruned leguminous shrubs. Experiments in Africa showed that corn yield increased when alley cropped with Leucaena (Fleury 1985). In the Thai upland area, rice yields did not decrease when interplanted with Leucaena (Brigati et al. 1984). In the hilly area in the Philippines, fruit yield increased when Leucaena was grown in hedgerows between the fruit trees (Moog 1985).

- ° Agroforestry integrates the forest with annual and perennial cash crop production. Experiments in eastern Java have shown that growing strips of fodder shrubs and trees with annual cash crops between bands of timber trees could meet the firewood, livestock feed, and food requirements of the farmers working in this area.

- ° Farmers usually propogate shrubs and trees by cuttings. Propogation by seeds, coppice, layrage, rhizomes, and grafting, however, have been carried out successfully in Nepal (Panday 1982).

- ° Cutting heights and intervals could affect production of Leucaena (Krishuamurty and Mune Gowda 1982; Siregar 1983; Guevarra et al. 1985). Cutting diameter could affect growth and yield of Gliricidia (Suarna et al. 1985).

- ° The intensive feed garden is intensive cultivation of fodder trees and grasses on small plots of land usually closed to the farmer's animal holding area (Atta-Krah et al. 1986). In this concept, with intensive nutrient recycling through application of manure and fertilizer, the goal is to provide major feed requirements for four to six small ruminants.

- ° The three-strata system involves growing grass (first stratum), shrub (second stratum), and trees (third stratum) so that the feed supply is available all year (Nitis 1984). In this system, the ruminant is fed mainly grass during the wet season, shrubs in the middle dry season, and tree leaves in the late dry season.

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INTENSIVE SYSTEMS BASED ON CROP RESIDUES AND CULTIVATED FODDERS

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Abstract *Large-scale intensive systems of small ruminant production are rare, but are managed to follow well-established principles of programmed provision of appropriate feeds. These feeds may be specially cultivated or obtained through integration with industries that guarantee by-products supplies. Small-scale intensive systems are more vulnerable because the use of crop residues and fodder crops is often more opportunistic. There are two requirements for the development of sheep and goat production programs scheduled to match periods of availability of different feed classes. First, there must be deliberate management of cropping rotations to allow the planned use of forages and crop residues for known numbers and classes of animals on a year-round basis. Second, preferential feeding of specific classes of animal is essential; however, this is successful only if intake and nutrient limitations throughout the whole life cycle are recognized. The nutritional conditions for improved reproductive performance, the consequences of periodic undernutrition during growth, pregnancy and lactation, and the likely interactions between nutrition and other environmental and management constraints are discussed in this context.*

There are few well-developed, intensively managed, commercial-scale small ruminant operations in any developing country. In such systems, the large concentrations of animals require a concentration of feed from large areas. The products (meat or milk) must be produced close to a concentrated market. However, the fibrous roughages that give the ruminants a nutritional niche are expensive to harvest, transport, and store. In some localities, food processing by-products provide the basis for intensive ruminant production systems; however, there are few opportunities that match feed supply and market proximity. Only in rare cases will easily accessible, highly productive arable land be used for the production of cultivated fodder specifically grown as sheep or goat feed. In some systems, however, crop residues are extensively used and integrated with some improved pasture and fodder production on less arable areas. Such intensive and semi-intensive systems are developing on a small scale in integrated crop-livestock smallholder communities. Individually owned small groups of animals are fed from small, noncontinguous tracts of otherwise unproductive land utilizing otherwise unproductive labour. Where the animals are penned at night, seasonally, or continuously, conditions for intensive management exist. This paper addresses systems of intensification based on crop residues and cultivated fodders, recognizing that often radical changes in the nature or the size of inputs required cannot be readily adopted, because of other contraints on the smallholder farms.

SMALL-SCALE INTENSIVE AND SEMI-INTENSIVE SYSTEMS OF MANAGEMENT

Small-scale goat and sheep production occurs primarily as a sideline to crop production or employment in other industries. The methods adopted involve simple strategies to use available feed resources, with minimal power input. Currently, small ruminants are viewed primarily as scavengers of feed and labour: few resources are directed to small ruminants that can be directed into cropping or alternative employment. The owner may be insensitive to improved husbandry techniques, resisting steps that divert resources from more profitable enterprises, involve changes in lifestyle, or have unforeseeable consequences. These "intensive" systems contrast sharply with large-scale commercial operations based on a monoculture involving high resource allocation. The "breeds" or types of sheep and goats kept in intensive systems differ between localities (Devendra and McLeroy 1982). While crossbreeds and exotics are almost always housed and intensively managed, native breeds often gain some feed by grazing at least for part of the year. Individual farmers, who may be landless, or cultivate less than 1 ha of land, usually keep 4-12 animals. The small ruminant enterprise depends on integration with crop rotation and the use of herbage grown on small areas of land not cropped. Improved feed materials are rarely grown specifically for goats and sheep. These animals are fed by exploiting the unmanaged plant growth on nonarable, often public land by using crop by-products, household wastes, and leaves of shrubs and trees grown around houses, fields, and plantations. Opportunities for selection of crop residues and cultivation of forages are limited. Hence, the nutritional value of feed offered is frequently inconsistent with requirements for high levels of production. While improvement of feeding value of fibrous crop residues by supplementation or chemical treatment has been given attention in research, the extent to which this has penetrated into sheep and goat production systems is low.

Digestibility of the herbage, voluntary intake, and nutrient yield are frequently limiting factors; however, recognition of times when particular classes of animals require special feed allocation (amount or type) is often wanting. Some farmers do have specific supplementation programs; they may or may not be appropriate. Competition among mixed classes of animals can reduce the effectiveness of supplementation. While separation of housed sheep and goats into classes (dams and newborn; males) occurs, this is usually not for reasons of nutritional management. Lack of knowledge or resources prevents the farmer from taking full advantage of intensive handling by preferentially feeding or supplementing target groups (pregnant, lactating, weaned, or sick animals) with appropriate feeds. The feeding is, in many instances, the responsibility of children, which may result in lapses in feeding procedures, especially as rural education programs develop and available time is reduced.

NUTRITIONAL CONDITIONS AND FEEDING PRINCIPLES

Housed animals are usually fed ad libitum, although the extent of excess and the potential for selective feeding is highly variable. A large proportion of the feed brought from outside the holding is composed of any available mixture of plant species that animals are known to eat, regardless of nutritional value. Crop residues may be fed as part of the diet and by-products such as rice bran are provided though the combinations are not always well chosen. Planned coincidences of animal production cycles with pasture crop residue shrub leaf available cycles in arable cropping or tree cropping systems are being devised (Moog 1986; Nitis 1987) and this often is more feasible with small ruminants than with cattle and buffalo. Weeds and grasses harvested from uncultivated, unfertilized land often include less palatable species, often are of low digestibility, and may be deficient in some minerals such as S and P (Little 1985). Alone, weeds and grasses rarely provide better than maintenance intakes.

Improvement of pastures with sown legume and better quality grasses is limited by common usage or exploitation problems. Few smallholders have developed special pastures for goat or sheep production. There are a few situations in several countries where areas of pasture grasses and legumes are grown to stabilize sloping lands and erosion-prone watersheds. The cultivation of improved forage species may be stipulated as a condition for government support or credit schemes for establishing small ruminant production units. Regulation of harvesting in such systems is difficult and realistic "stocking rate" relationships should be established in priority feeding programs to provide the best nutrient sources to those animals with the greatest requirements.

Mature ruminants can maintain weight on most herbages and crop residues offered ad libitum if digestibility is 55% or better. As a broad rule, as feed digestibility increases, so does voluntary intake. Many empirical studies of combinations of feeds have been reported and reveal associative effects on total intake, digestibility, and production. Complementarity of feed components, as, for example, feeding high protein herbages with low nitrogen crop residues, provides a simple guideline. The principles of complementarity extend to manipulation of the rumen environment and to provision of nutrients that bypass rumen fermentation and proceed to the small intestine. These aspects are poorly explored for tropical feeds, but have been discussed by Dixon (1985), Egan et al. (1986), and Leng (1986). Strategies to combine feedstuffs generally aim at making maximum use of the more abundant, lower digestibility roughages while animals are in a maintenance phase and at reducing the contribution of these roughages to the diet as physiological demand increases for growth, late pregnancy, or lactation. The relationship between nutrient supply and requirement is shown in Fig. 1. Either individual animals with the greatest demand are supplied preferentially at any time of the year or all animals are brought to simultaneous high demands in those seasons where the high nutritive value feed is most abundant. In either case, productivity targets must be realistic in relation to feed supply.

FEEDING SYSTEMS, CROP, AND FODDER PRODUCTION

The need to commit a major portion of land to the production of food crops limits the area that can be used for forage crops. Rotations of staple crops and vegetable or grain legume crops provide harvest residues and crop by-products for rumi-

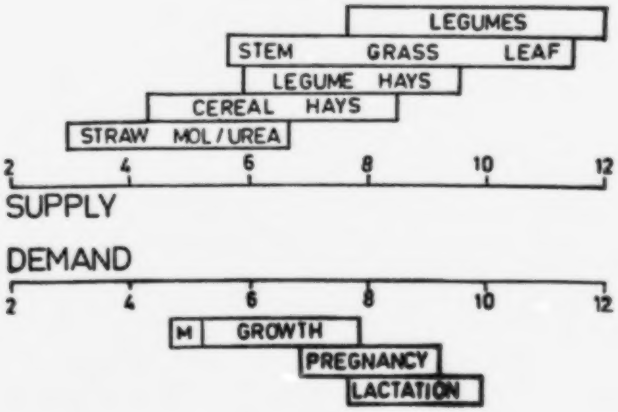

Fig. 1. Relationship between the protein energy supply of a range of temperate feedstuffs and the demand of producing ruminants (M, maintenance). Similar data is needed for tropical feeds and animals. Supply and demand are indicated as grams protein digested in the intestine per megajoule of metabolizable energy.

nants. In some cases, forage crops can be incorporated in the rotation or grown in association with the food crops (Cornick and Kirby 1981). For small holders, such systems invariably involve seasonal collection of weeds and shrub and tree leaves. Fields of standing stubble from irrigated rice will often yield rice plant regrowth and weeds of reasonably good nutritional value for animals tethered or grazed. Selective harvesting of this green material for cut and carry systems is often practiced. The period of availability and the stock numbers that can be supported are limited. Rice straw is a highly variable harvest by-product. Depending on cultivar, soil moisture conditions, stage of maturity at harvest, harvest weight, and conditions of storage postharvest, digestibility can range from 30 to 55% (Pearce 1985). Intake also varies from 1.0 to 2.7 kg per 100 kg live weight for goats and sheep. Both species will practice selection if given the opportunity, although the basis of acceptability of different rice straws has been poorly studied. Leaf, leaf sheath, and stem internode are often of similar digestibility and the relationships between straw morphology, proportion of cell contents, N content, digestibility, and acceptability are currently being studied (Doyle et al. 1987). Usually, however, rice straws will not permit the maintenance of live weight of sheep or goats. Chemical treatment with, for example, lime or urea-derived ammonia can improve intake and digestibility of rice straw, although acceptability problems and highly variable intakes are encountered. Such a treatment is often too expensive for the smallholder to consider and the improvement afforded still fails to support the intake needed for growth, late pregnancy, or lactation.

Forage crops, grown as intercrops, relay crops or companion crops improve the yield of good-quality ruminant feed. Experimentation with such systems indicates possible combinations that result in little or no reduction in cereal crop yield (Moog 1986). Season availability of companion crop as harvestable green feed for cut and carry systems, however, often coincides with availability of weeds and grass growth on uncultivated land. Left to maturity to improve residual roughage after cereal harvest, these materials lose nutritional value. Some legumes grown as dual-purpose crops in a relay cropping system utilizing residual soil moisture in paddy fields offer the opportunity to support extra production. Likewise, forage legumes grown on paddy banks can be used either as a harvested feed component or as a grazed supplement to stubbles. Digestibility, protein content, and intake of many legumes is higher than that of grasses at similar maturity.

Forage and grain legume harvest residues vary widely in feeding value for small ruminants and between species of ruminants (Table 1). The stage of maturity at which harvest is made affects the nature of the residues. For cowpeas picked as immature pods, the residual stubble may still be green and of high digestibility. For soybeans harvested at maturity when the plant stem is drying, digestibility of stem material is low. At harvest, some grain legume straws and stubbles are left in the field; with others, however, the whole plant is harvested and the legume seed is recovered by whole-vine threshing. The latter procedure can result in stem, leaf, and pod or hull residues being separated as different components for subsequent use as components of mixed-material diets. Consequently, in considering feeding value, the crop residue must be described quite specifically.

As with most crop plants, there is considerable dry matter loss, decreased protein carbohydrate content, and increased fibre content with approaching maturity of the plant. For most

Table 1. The nutritive value of pigeon pea harvest trash for goats, sheep, and cattle.

Species	Mean LW (kg)	Voluntary intake (g/kg LW)	DMD (%)	DDM (g/kg LW)
Goats	39	25.7a	47.3a	12.2
Sheep	56	21.7b	50.9a	11.0
Cattle	216	25.1a	54.6b	13.7

Notes: LW, live weight; DMD, dry matter digestibility; DDM, digestible dry matter. Values followed by the same letter are not significantly different ($P > 0.05$).

Source: Whiteman and Norton (1982).

of the common food legumes, however, the stem material is of better digestibility and slightly higher nitrogen content than cereal straws. Leaf digestibility is high, but for some legume crop residues at maturity, leaves may contribute little to the material recoverable by animals grazing stubbles or hand fed vine-threshed materials.

With respect to soybean fodders, it is probable that data on soybean hay (unharvested crop) and soybean stubble (residue following harvest) have been confused in some reports on composition and nutritional value of "straw." At the low end of the scale, intake of digestible energy will not support live weight maintenance; at the upper end, however, respectable gains are made by sheep (120 g/d) (Table 2). Soybean straw containing 6-7% crude protein has an organic matter digestibility between 35 and 50% and appears to be well accepted by goats. During threshing of hand-harvested soybeans, leaf and pod residues and stem separate. The stem material will typically have an organic matter digestibility of 25-30%. Although intake of stem may be as low as 1.5% of live weight, the itake of leaf pod fraction fed alone can be up to 3.8% of live weight (Cheva-Isarakul and Saengdee 1985). As a general rule, intake decreases with decreasing nitrogen content and digestibility. Acceptability and intake, however, are not governed by these

Table 2. In vitro digestibilities of harvest straws (stem and leaf fractions).

Straw	IVOMD[a] (%)	Nylon bag (48h) loss (%)	Source[b]
Soybean	14.7-38.4	16.4-40.5	1,2
Pigeon pea	34.8-52.4	-	3
Cowpea	39.6-48.2	45-53	4,5
Field bean	40.1-56.8	38-54	1
Faba bean	31.4-55.5	-	6

[a] IVOMD, in vitro organic matter digestibility.

[b] 1, A.R. Egan and W.G. Allden (unpublished); 2, Ayers and Denney (1986); 3, Whiteman and Norton (1982); 4, Roxas et al. (1985); 5, A.R. Egan and Lowrey (unpublished); 6, A.R. Egan and Radcliffe (unpublished).

factors alone. Ayres and Denny (1986) examined "better quality" soybean stubbles as feed for sheep and found for a "better quality" stubble material (consisting of 80.9% stem, 18% pod, 0.9% seed, and 0.2% leaf fragment); organic matter digestibility was about 50%, but intake was only 1.0% of live weight. Supplementation with urea and molasses did llittle to improve intake, digestibility, or animal performance, indicating that nitrogen deficiency was not the limiting factor.

Cowpeas (Vigna unquiculata L.) can be grown as a dual-purpose crop. Where pods are hand harvested, the green stem and leaf material (50-70% of the harvestable biomass) has 14-16% crude protein and a digestibility of 55-65% (Bhaid and Talaptra 1965). This residue will support good growth in goats. If the crop is allowed to mature, however, protein content of residues falls to 10-11% and digestibility declines to 45-55% (Roxas et al. 1985). Intake of such residues is reduced to about 1.8% of live weight, just maintaining live weight of sheep and goats. Pigeon pea harvest trash (mixed pod leaf, and stem) had a higher feeding value than pod alone (Whiteman and Norton 1982). The proportion of leaf within the mixture will have a major effect on protein content and nutritive value. Limitation to animal performance was suggested by Whiteman and Norton (1982) to arise from the low sulphur content of the constituents of pigeon pea harvest trash.

Of major importance, is the recognition that the feeding value of a harvest residue is dependent on the level of availability as provided to the animal. If able to select, some animals may, for example, choose a higher proportion of powdered leaf material, increasing the protein content and digestibility above that of the material selected by others. Sheep and goats may differ in this respect. The question of selective preference raises at least one aspect of differences between species and between animals adapted or trained to different feeds and feeding systems. These questions lie beyond the scope of the present paper, but such considerations must be accommodated in tests of feeding value of these classes of feedstuffs.

There is little comparable information on the composition and digestibility of residues of other tropical food legumes used in sheep and goat feeding systems. Certainly, mung bean, peanut, chick peas, lab-lab bean, yam bean, rice bean, sword bean, and jack bean provide forage materials and residues for use as animal feeds; however, little systematic work on the use of the harvest residues is available.

SUPPLEMENTATION AND COMPLEMENTARITY OF FEEDS

Dixon (1985) and Leng (1986) have reviewed the principles involved in choice of supplements from among available alternatives. Roughages of low digestibility or long ruminal retention time require supplementation to increase the rate of intraruminal digestion and improve the efficiency of microbial protein production. Often, N, S, and P are the main nutrients required and can be provided in available shrub and tree leaves. Supplementation with rapidly fermented concentrated forms of energy depress the rate of fibre digestion. This will result in substitution of the supplement for the roughage in the animals' total intake (Dixon 1985). The aim is to build the total supply of nutrients towards the optimum pattern and achieve intake levels of the combination of components that is adequate for the desired performance. Some roughages such as poorer classes of rice straw or elephant grass stem are poor sources of nutrients in the sense that the rate of digestion is not much improved, even when other sources of microbial nutrients are provided. The physical properties of many straws and coarse tropical grasses restrict the rates of comminution and of removal of particles from the reticulorumen, resulting in low intake (Egan et al. 1986). Supplements may not always improve rates of outflow of the relatively indigestible residues from the reticulorumen. Components such as leaves and twigs or shrubs, or stems of tropical legumes, while providing protein and readily digestible components, may contain a slowly degraded, slowly comminuted fibrous fraction that adds to the fibre load to be removed from the rumen. Thus, supplements like leucaena used to increase the intake of moderate quality rice straw may lead to no increase or even a decrease in roughage intake (Doyle 1987).

Heat production in a high-temperature, high-humidity environment also imposes a limitation on intake level and feeding patterns. The effect is greatest where very high intakes and, hence, heat production are necessary to support growth and lactation. It is particularly exacerbated when confinement at night compels grazing animals to consume their entire intake at the hottest times of the day. The problem of heat stress will increase if nutritional and genetic limitations on performance are reduced. High intakes of feed will result in increased heat production from fermentation and metabolism, thus imposing a new ceiling on production. Support feeding at night with crop residues or cut herbage and tree leaf may improve overall intakes. There is also possible benefit in providing more nutrients in forms that avoid ruminal fermentation and are digested in the small intestine. Likewise, provision of nutrients in balances which minimize heat-yielding metabolic interconversions in the animal may be of greater importance because of the greater implications for intake and the direct effects on metabolic efficiency (Egan 1976). The time of day when peak absorption and metabolism occur may also be important.

More sophisticated nutritional strategies to improve intake and total nutrient yield by programmed feeding of different dietary components (Egan et al. 1987) have yet to be effectively developed. Preliminary evidence is that nutritional conditions can be improved without necessarily requiring altered feed supplies. Less regular feeding of some components (concentrates or highly digestible leaf material) in larger amounts at a given feed can result in cycles of intraruminal conditions and digesta flow that optimize the positive and the adverse associative effects. Over the longer period, this can lead to increased total intake and nutrient yield (Table 3). In some circumstances, such small gains with no change in total feed used may be more valuable than larger gains requiring greater or different feed resources.

Mineral deficiencies (S, P, Na, I, Cu, Co) are likely in many areas (Little 1985). These cannot always be dealt with sensibly by application of fertilizer, particularly where feed is harvested from "unproductive" land. Hence, either the feed component mixtures must include species chosen on the basis of likely mineral adequacy or cheap mineral supplements must be provided directly to the animal.

NUTRITION AND REPRODUCTIVE PERFORMANCE

The mixed origins and varied management in intensive goat and sheep systems makes generalization about reproductive performance difficult. Short parturition intervals and high proportions of multiple births are frequently quoted. Yet, long parturition intervals and poor litter weight weaned are common problems.

In most village sheep and goat systems, there is no apparent photoperiodic seasonality in reproduction; but nutritional seasonality may be marked (Obst et al. 1980; Bell et al. 1983; Simpson 1985). With confined animals there is no evidence of widely practiced routines of planned mating in relation to patterns of feed availability or market prices (Fletcher 1985; Falvey 1985). Breeding systems are not well organized and much of the discernible reproductive inefficiency may be due more to a lack of biological knowledge or purposeful management than to other major environmental constraints. Even with confined animals hand fed once or twice daily and potentially under close surveillance, the onset of oestrus may not be recognized. If bucks or rams have to be borrowed, mistiming of mating often occurs. In a village study by Bell et al. (1983), some ewes being held for mating were not in oestrus; 5 of 55 ewes mated were already pregnant and only 13 of the nonpregnant ewes conceived to that mating. Nutrition, if a problem, is clearly not alone.

While factors affecting performance in a single reproductive cycle have been examined (Obst et al. 1980; Knipscheer and Kusnadi 1983), overall lifetime reproductive performance has

Table 3. Live weight and wool growth of pasture-grazing, supplemented, weaner wether sheep.

Treatment[a]	Live weight change over 90 days (kg)	Wool growth (90 days) (mg/day)
Control	-1.9a	58.1a
O x 1	-0.3b	60.1a
O x 3	+0.3bc	73.1bcd
T x 1	-0.4b	63.0ab
T x 3	+0.7c	74.0bcde
L x 1	+0.2bc	75.8bcde
L x 3	-0.2bc	72.0bc
SM x 1	+0.2bc	81.4cde
SM x 3	+0.6c	74.1bcde
FSM x 1	+0.5bc	87.8e
FSM x 3	+0.8c	86.6e

Note: Values followed by the same letter(s) are not significantly different ($P > 0.05$).

Source: Egan et al. (1987).

[a] Sheep were supplemented daily (x1) or once every 3 days (x3) at an average rate of 150 g/head per day. O, oats; T, triticale; L, lupins; SM, sunflower meal; FSM, formalin-treated sunflower meal.

been poorly evaluated for sheep and goats raised intensively in the tropics and subtropics. Some workers (e.g., Khusahry 1985), consider that in their specific environment there is no major problem with reproduction. The performance of existing breeds as revealed under favourable environmental conditions

conditions with good management indicate no inherent fertility problem. Repeatability of litter weight at birth or at weaning is low (Bess et al. 1985), however, indicating either major environmental effects or negative correlations between components of performance in successive pregnancies.

The important performance trait, litter weight at weaning, combines aspects of dam reproduction (ovulation rate, embryonic survival, and foetal growth rate) and offspring survival and growth (birth weight health, mothering ability, and colostrum and milk yield). Data from Bell et al. (1983) indicate litter weights at weaning of 12-15 kg/ewe per year and 10-12 kg/doe per year. In well-managed experimental conditions, this can be improved four- to five-fold, even where weaning takes place at an earlier age. In village systems, lifetime weight of offspring weaned for does is 60-90 kg and 250-360 kg in better nutritional and management conditions. Beilharz (1986) has argued that in an adapted population, lifetime reproductive performance is at a maximum in equilibrium with specific environmental conditions. Without improvement in environmental conditions, an increase in one component of reproductive performance will attract a compensating loss at one or more steps during the subsequent lifetime reproductive pattern. This is expressed in the often-noted negative correlation, in a given environment, between litter size and survival rate of offspring and the positive correlation between weight of surviving offspring at weaning and parturition interval.

Nutritional history and live weight of the dam, particularly age and weight at first mating have been noted to affect performance in intensive small ruminant production systems (Obst et al. 1980). Holmes and Mott (1986) have shown a significant increase in kidding interval in does mated for the first time at low live weight and a significant effect of doe live weight and litter weight at parturition on interval to next kidding and subsequent litter size (Table 4). Knipscheer and Kusnadi (1983) found that where doe live weight was lowest in village conditions, kidding interval was longest. With ewes, however, Bell et al. 1983 observed that in a range of nutritional and management conditions supporting different lactation levels and lamb growth rates, return to oestrus did not appear to be a major factor limiting subsequent reproductive performance. No data on subsequent litter size was provided.

In examining reproductive response to current nutrition, a number of important nutritional interactions become clear. Past nutritional conditions (reflected in size of labile reserves) can modify effects of current nutrition. Some steps in reproduction that appear to respond to extra nutritional inputs do not impose a high demand for energy or for specific nutrients. The response of ovulation rate to a sudden and short-term increase in nutrient inputs (Lindsay 1976) is mediated by hormonal responses to those inputs (Oldham and Lindsay 1984). Minor shifts, therefore, in live weight and current nutrition may have marked effects on ovulation rate, implantation, and, therefore, potential litter size. Later in gestation, as major energy demands are made, body reserves and sporadic and unregulated provisions of extra feed may not provide the nutritional environment for good foetal growth, mammary development, and subsequent lactation, although litter size may not be affected. For Indonesian conditions, Fletcher (1985) identifies nutrition during late pregnancy and early lactation as a principle factor limiting goat reproduction. Crop residues and by-products are often fed when available to all animals regardless of the usefulness these might have in meeting the varied requirements of animals in different physiological states. Overall reproductive performance could be improved by scheduling mating to allow allocation of better quality feeds in greater quantities to does and ewes at those stages. This should improve lifetime reproductive performance, but will not necessarily show a discernible effect on any one criterion such as litter size or litter weight at weaning.

There is an observable improvement of litter size and offspring survival rates associated with increasing altitude (Astutu et al. 1984; J.M. Obst, personal communication). The components of such a correlation can include a diversity of environmental varibles: e.g., nutrition, disease status, climatic environment, management practices, and their interactions. It is often proposed that indigenous livestock are adapted to their climatic environment and, therefore, performance should not be limited by those conditions. This is not necessary a logical argument about the nature of adaptation. Holmes et al. (1986) have provided evidence that, in adapting to cope with high temperature and humidity (35°C, 70% relative humidity), the physiological effect in pregnant does was reduced foetal growth, particularly affecting multiple foetuses. Perinatal mortality is increased and low birth weight kids have a high probability of succumbing to subsequent problems. Doe lactation level is also reduced. From doe live weight patterns, it is clear that altered partition of nutrient

Table 4. Interval from parturition to next conception (days, SEM = 29 days) in relation to previous litter size (single or multiple) and lactation.

	Single		Multiple	
	Interval to conception	No. conceiving during lactation	Interval to conception	No. conceiving during lactation
After first litter	89	4 of 5	212	0 of 2
After second litter	20	2 of 2	144	0 of 1
After third litter	76	2 of 3	115	1 of 5
After fourth and subsequent litters	32	2 of 2	107	4 of 6
Total		10 of 12		5 of 14

Note: Kids were weaned 112-120 days postpartum.
Source: Holmes and Mott (1986).

use, which is possibly a consequence, in part, of altered food intake and blood flow patterns, occurs (Ocfemia et al. 1987). Feed materials with the potential to support high intakes and provide a good balance of essential amino acids and gluconeogenic precursors may not produce the predicted response. Far more work is needed in this area. While nothing can be done about the climate, the site, and design of housing to take account of aspect, shade, and air movement, the timing of feeding and availability of drinking water can moderate extreme adverse conditions. For pregnant and lactating does and ewes, small improvements may have far-reaching effects on lifetime productivity.

Over several studies of intensive goat production systems in Southeast Asia (Devendra and McLeroy 1982) mortality ranges from 4 to 20% at birth and from to 13% from birth to weaning.

The contributing factors are diverse, including separately or collectively, low birth weight, poor mothering ability, poor milk production, disease, and environmental stress. Cocciodiosis, pneumonia, septicaemia, helminthosis, enterotoxaemia, and melioidosis are the major identified disease states. Some of these may be effects of close confinement and poor housing interacting with poor nutrition of the dam.

Low birth weight is a serious disadvantage and is often associated with poor colostrum and milk intake and slow growth rate (Alexander 1984). This may reflect effects of poor nutrition, low health status or heat stress in the doe, or large litter size, each of which contributes in other ways to the complex conditions that predispose offspring to debility and mortality from other causes.

Subandriyo (1985) found that under village and experiment station conditions in Java, litter weight at birth increased with ewe age up to 4 years of age, but this did not carry through to a significant effect on litter weight at weaning. Weaning weight of individuals is markedly affected by litter size at birth, even where little size is adjusted downwards by removal of one of a set of triplets (Bess et al. 1985). This is more marked in villages, than on field stations. The litter weights for single, twins, and triplets were in the ratio 1:1.4:1.65 in the villages system compared with 1:1.5:1.8 at the field station. At weaning, twins sustain their litter weight advantage over singles, but triplets suffer an increasing penalty and litter weight falls below that for twins even if they survive. Improved nutrition may reduce this effect, but limitations on the dam's intake, body reserve status, and capacity to mobilize must be more thoroughly explored in the tropical environment. Some evidence suggests that the Kacang goat produces insufficient milk to support maximum growth rate of a single kid even when fed ad libitum on diets including concentrates (Khusahry 1985).

NUTRITIONAL CONDITIONS FOR POSTWEANING GROWTH AND PRODUCTION

Average growth rates of lambs and kids of 80-100 g/d are achievable on immature grass and fodder crop alone but are not exceeded without substantial amounts of concentrate in the diet (J.M. Obst, personal communication). Voluntary intake of digestible energy and protein digested in the small intestine are the primary limiting factors (Egan 1984). Growth rates of 20-40 g/d for lambs in village systems can be improved by shrub leaf supplementation (Mathius et al. 1984). There can be wide variation in the material harvested and fed each day, however, and guidelines on selection of material for feeding are needed. Surges in growth rate are associated with periods of provision of feeds of 70-75% digestibility, inclusion of concentrated by-products, cassava chip, and high protein feeds such as legume forage or immature grain legume hay.

Continuous rapid growth is not always achievable. The traditional "intensive production" objective of rapid and continuous growth to market weight is not appropriate in an environment where there is an unstructured market relatively insensitive to price per unit weight. Severe and continuous undernutrition, particularly if compounded with parasite or other disease problems, can result in permanent stunting. Periodically undernourished animals will recover normal rates of growth and levels of performance, however, when provided with improved nutritional conditions (Allden 1972). Metabolic efficiency and appetite during such recovery have not been studied for the tropical environment. While animals have a capacity for compensatory growth, expression of this phenomenon depends on their ability to ingest more feed or to partition more absorbed nutrients into lean tissue growth (Allden 1970). The ability of small ruminants to achieve compensatory ("catch-up") growth when fed tropical roughages in a hot, humid environment deserves investigation. Systems can then be considered in which particular problems of seasonal feed supply can be dealt with on the basis of optimized irregular growth paths. This can be important in achieving target weight for first mating that fits young replacement does and ewes into the management time table.

There is also the need for continuation of growth of young ewes and does during their first pregnancy and lactation and this imposes greater and more specific demands for nutrients. Because of the lack of locally derived information, the requirements of different classes of ruminants are currently assumed to be like those of similar classes of animals in temperate environments (Orskov 1980; Leng 1986). Although the needs of animals for specific metabolites can be estimated from such work, the tropical feedstuffs have not been well studied in terms of the yields of nutrients such as protein, acetate, gluconeogenic substrates, lipids, vitamins, and minerals. Voluntary intake levels for young sheep and goats with high growth potential fed native grasses and crop residues are quoted in many publications. However, the interactions of animal growth potential or physiological state with other factors influencing intake such as digesta passage rate, nutrient balance, heat production, and environmental temperature have not been adequately investigated.

CONCLUSION

Intensive small ruminant production systems are appropriately established at the smallholder level in many countries. There is immense scope for improvement of efficiency of production in such systems. The utilization of crop residues and cultivated fodders enables the development of simple year-round operating time tables consistent with the assessed seasonal feed supply and the labour commitments in other activities. Opportunities for production of special-purpose fodder crops for small ruminants are limited, but cropping systems are being developed that will improve this situation. Instruction in the principles of animal feeding and breeding, and in construction of housing to permit preferential feeding and treatment of young, pregnant, lactating, and sick animals will provide major improvements. More sophisticated supplementary feeding practices, where necessary for optimum animal performance, can be introduced only when the basic management skills are well developed and farmers are receptive to changes related to improvement of reproduction and growth efficiency rather than simply aim to increase numbers of animals held.

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DISCUSSION

The six papers in this session were devoted to production systems and set the stage and pace of the workshop. The first paper, presented by Dr R.D. Hart, highlighted the interrelationships among the sociological, economic, and biological factors present in a regional farming system and showed the hierarchical nature of the interacting parts. Within this, livestock systems, specifically those involving small ruminants, can be identified and studied, but not separately from the wider systems within which they operate.

Case studies showed how the hierarchical structure can provide a common structure for studying a livestock system at the regional, farm, and animal levels. Based on this, an analytical system was proposed that traces the flow from inputs through resource pools to outputs for factors at any level of the hierarchy. The separate factors can then be connected through the resource pools.

Although it would be difficult to complete an overall numerical analysis of the wider systems constructed using this analytical framework, it contributes to an understanding of the network of interrelationships that assist greatly in deciding on research and development investment. It is important, however, to remember that this approach and, indeed, all systems research requires the availability of alternative technology and an aim to develop alternative production systems.

Discussion emphasized the value of this type of systems approach even for animal scientists not working in a farming systems research team. The important fact that even small improvements in technology may result in large overall effects because of interactions with other components of the system emphasized the need to study relationships with the next highest level of the hierarchy.

The main problem areas relate to converting the descriptive framework to a numerical basis and to the development of satisfactory methods for analyzing capital flow in the system.

The second paper by Dr C. Devendra drew attention to main features of small ruminant systems in the Asian region and the use of production resources. It was emphasized that these resources were essentially traditional but made important contributions to the social and economic stability of the families on small farms. The fact that almost all farmers can maintain these resources with ready integration into the cropping system makes them a primary area for development. Unfortunately, small ruminants lag well behind the other components of the farming system in the work that has been done up to now and this explains their low level of production.

The paper showed that although many of the important features of the animal resources have been described, their potential has not been investigated. Particularly important issues in this regard are the development of intensive systems based on cultivated forages combined with stall feeding and systems integrated with tree cropping that have great potential. Examples of these are the grazing of small ruminants under coconuts, rubber, and oil palm.

It was clear that the most severe constraints to improvement of small ruminants were associated with feed resources from the aspects of both provision of feed and its utilization by the animals. Thus, this aspect merited major attention. Large changes in systems would not be likely, however, unless a new technology was clearly superior. For most effectiveness, changes would have to be gradual, they would have to be based on making the maximum use of feed resources, and the system would have to include effective delivery systems for the essential supplies of feed and the need for intensification to increase productivity to meet both national and export market demand was stressed.

Discussion concentrated on the integration of small ruminants into the cropping systems and problems associated with the attitudes of plantation managers and the lack of sound animal science information. Some of the attitudes could be changed by education, but there is an urgent need for research into both the animal production aspects and the effects of the animals on crop yields.

The third paper, presented by Dr W.L. Johnson, focused on feed resources and feeding systems. Two important goals of small ruminant systems are based on the need to integrate all farm livestock and crops, the abundance of grasses and low-quality crop residues, the relative lack of high-quality feed and grain for small ruminants, their relatively low productivity, and the fact that farmers are not likely to outlay cash to feed them: first, the maximum use of available resources and, second, the development of supplementation systems to optimize production.

The paper stressed that diets composed only of crop residues and grasses could only maintain body weight with little production because of the limited ability of small ruminants to digest fibre. Alternatively, diets consisting of foliage from crops and shrubs could support higher production levels but suffered from problems associated with specific plant components. A balance could be achieved if available forage resources were used to the maximum extent with the use of higher quality material to enhance digestion and provide moderately improved production. In this context, an important benefit could be obtained from the selectivity of the animals (particularly goats) if feed offered was considerably more than required.

Discussion raised the question of how practical methods of feed analysis could be developed to aid in the operation of the feeding system. Techniques of assessing neutral detergent fibre and ammonia concentration of rumen fluid were suggestions that have been shown to be feasible in field studies.

The fourth paper, presented by Dr D.A. Ivory, highlighted the problems associated with the great fluctuations in availability and quality of annual crop residues. These problems necessitate the development of storage methods, cropping systems that would spread supply, and animal management systems to better fit requirements with residue availability.

There is a considerable body of knowledge on the value of residues but little information on the development of systems for their use. Such systems will almost always have grass as a major component so research on grasses will likely lead to improved systems.

In comparison to Dr Ivory's paper, Dr I.M. Nitis dealt with production systems based on tree cropping. He emphasized the wide range of trees that could contribute to small ruminant production systems and the variety of such systems that can be devised. Simply on the basis of the extent of tree cropping, there is enormous potential for increased small ruminant production if suitable systems can be developed and adopted. To a certain extent, there is already integration of animal production with tree cropping in dryland areas with less in cultivated regions. There are important seasonal differences in both availability and use of tree leaf, but the main determinants of use are related to cropping factors rather than animal requirements.

Discussion developed possibilities of alternative storage and feeding methods for tree leaves and indicated that these could provide extended value for small ruminant feeding, including during periods of feed scarcity.

The last paper in this session, presented by Dr J.H.G. Holmes, emphasized that, with crop residues and cultivated forages, there is usually a conflict between residue quality and availability. There are also problems with the effects of management systems on the feed requirements of small ruminants.

The overall digestibility of residues has a primary effect on their value with maintenance of body weight being unlikely at less than about 55%. Aspects of diet selection by animals and differing requirements for nutrients between species, however, make it difficult to generalize about the suitability of different feeds.

Information is accumulating on the agronomic and nutritional aspects of residues and forages, but there is little known about the direct effect of intensive management, practices on reproductive efficiency, tolerance to environmental stress (particularly heat), and overall production. It is likely that these factors could be limiting small ruminant production in situations where there are well-established feeding systems.

Session II

Country Case Studies — Issues and Problems

INTEGRATED CROP AND SMALL RUMINANT SYSTEMS IN NEPAL

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Abstract *Small ruminants are of paramount importance in Nepal. They are found in small land holdings, produce meat, and are equally valued for the production of manure and cartage of basic necessities of the hill people. Export commodities of raw materials from small ruminants, such as carpets, woollen garments, and skins, are a major source of foreign exchange for the country. The transhumance production system is a practice adopted by the people to meet the acute problem of feed shortage in the hills. The grazing system is synchronized with climate, season, availability of feed, cropping system, cultivation pattern, and socioeconomic practices of the villages. The system is constrained, however, by restricted grazing as a result of the cultivation pressure of land, high livestock density, overutilization of pasture land and forest, high grazing fees, and heavy losses because of mismanagement of flocks, predators, and poisonous plants. Crop residues and by-products from cropland account for nearly 49.7% of total digestible nutrients utilized in the country and are the major sources of feed for animals in the hills and terai. The utilization of feed resources integrated with human food crop production holds the best prospects for development of feeds to avoid depletion of forest resources and to arrest the degradation of the mountain ecology.*

Nepal is a small country capped by some of the highest mountains in the world with deep gorges and valleys, fast-flowing mountain rivers, and the highest lakes in the world. The ragged terrain of the mountains, although scenic, is a handicap for the economic development of the region. It has thwarted all development efforts because of remoteness, inaccessibility, and distance from the main vein of the marketing centres in the south. The total area of Nepal is

147,000 km^2, of which two-thirds is mountainous and one-third is terai plains. As of 1984, the human population was 16.4 million; the growth rate is 2.7%. Population density is 111 persons/km^2. As of 1981, the literacy rate was 2.3% and the infant mortality rate was 15.2%.

The gross domestic product (GDP) for 1982-83 is NPR 20,642 million (in 1986, 20 Nepalese rupees (NPR) = 1 United States dollar (USD)). Agricultural and livestock products are responsible for 68.8 and 15% of the GDP, respectively. The contribution of small ruminants is about 3.8%. Livestock is an integral part of the agricultural and social life in the country. Livestock for the mountain people provides manure, power, milk, meat, and fibre to meet the basic subsistence requirements of the hill economy. The whole country can be broadly classified into three major ecological-physiographic regions: mountain (trans-Himalaya region at an altitude of 2500 m and the high mountain region also at 2500 m), hill (including the midhills at 1500-2500 m and the low hills at 300-1500 m), and terai (at $<$ 300 m).

DISTRIBUTION AND GROWTH RATE OF SMALL RUMINANTS

The total population of small ruminants is 5.67 x 10^6 and the ratio of sheep to goats is 1:6.22. The majority of sheep is concentrated in the western regions of Nepal, especially the midwestern region (47.9%). The goat population tends to be evenly distributed in all development regions, but the central and eastern regions account for 57.8% of the total goat population (Table 1). The sheep population is more concentrated in the hills and mountains (87.5%), whereas goats are in the hills and terai (84.6%). Goats are unpopular in high mountains because they are more susceptible to cold weather.

The growth rate of sheep and goats is 2.94 and 2.78%, respectively. The growth rate of small ruminants is quite high in the hills and mountains (1.57 to 4.35%), but not in the far-western regions, where it is quite negative (-1.37 to -2.09%).

A substantial change in population of small ruminants was noticed in the last 2 decades. The original estimate of sheep population 1.975 x 10^6 was drastically reduced to 0.785 x 10^6 and the goat population estimate rose from 2.1 x 10^6 to 4.88 x 10^6. The original ratio of sheep to goats of 1:1.06 changed to 1:6.22 with the refinement in survey data collection and processing.

Table 1. Population distribution and growth rate of small ruminants in different developmental and ecological regions of Nepal.

	Sheep			Goat		
Developmental and ecological regions	No.	(%)	Growth rate (%)	No.	(%)	Growth rate (%)
Eastern						
Mountain	36524	(4.8)	4.23	177461	(3.6)	3.25
Hill	71952	(9.2)	3.38	725686	(14.9)	4.35
Terai	5745	(0.7)	0.18	442410	(9.1)	2.47
Subtotal	114221	(14.7)	-[a]	1345647	(27.6)	-
Central						
Mountain	53178	(6.8)	2.68	240131	(4.9)	3.81
Hill	47413	(6.0)	3.82	735864	(15.0)	1.67
Terai	7195	(0.9)	2.24	501855	(10.3)	3.19
Subtotal	107786	(13.7)	-	1477850	(30.2)	-
Western						
Mountain	6920	(0.9)	1.57	77600	(1.6)	4.18
Hill	107671	(13.7)	1.87	745300	(15.3)	2.82
Terai	14582	(1.9)	3.72	175520	(3.6)	-1.72
Subtotal	129173	(16.5)	-	998420	(20.5)	-
Midwestern						
Mountain	218652	(27.7)	4.26	162374	(3.3)	3.89
Hill	107929	(13.7)	4.23	429234	(8.8)	4.34
Terai	50869	(6.5)	-0.12	130853	(2.7)	3.60
Subtotal	377450	(47.9)	-	722461	(14.8)	-
Far western						
Mountain	36589	(4.7)	-2.09	97759	(2.0)	-1.90
Hill	939	(0.1)	-2.34	163093	(3.3)	-1.37
Terai	18994	(2.4)	-0.63	77095	(1.6)	4.15
Subtotal	56522	(7.2)	-	337947	(6.9)	-
Nepal						
Mountain	351863	(44.8)	-	755425	(15.4)	-
Hill	335904	(42.7)	-	2799177	(57.3)	-
Terai	97385	(12.5)	-	1327733	(27.3)	-
Total	785152	(100.0)	2.94	4882335	(100.0)	2.78

Source: Department of Food and Agriculture Marketing Services, 1985.

[a] Total growth rate percentages were not estimated at the original source.

The popularity of goats is primarily because they are easy to raise. Sheep raising under a transhumance system of management in the hills, however, is affected by the increasing amount of land being devoted to cultivation, the shortage of grazing areas in the hills, and the overutilization of forest and pasturelands.

IMPORTANCE OF SMALL RUMINANTS

Meat production from small ruminants (28,032 t) accounts for 22.0% of the total meat produced (sheep, 2%; goats, 20%) and they account for 94.6% of the total animal fibre production (674.8 t) (sheep, 94%; goats, 0.6%). The demand for small ruminant products, e.g., meat and wool, is constantly increasing. Fifty-six percent of the total manure produced by small ruminants (383,000 t) is recovered by night camping in the field and night soils from the sheds. The stronger, heavier small ruminants are used for carting and hauling in the far-western regions of Nepal. The total load transported across the mountains is about 912.8 t/year.

Carpets, woollen goods, and skins produced from small ruminants is gaining popularity in export trade. In 1982-83, it accounted for 82.1% (i.e., NPR 237 million) of the total export trade of NPR 289.7 million. Although the total export earnings from small ruminants rose to NPR 475.5 million in 1984-85, the share in total exports was reduced to 43.0% with the rise in the proportion of ready-made garments for export.

Export-oriented, animal fibre based cottage industries, e.g., carpet and woollen industries, are under constant strains with the shortage of suitable locally produced raw wool. The industries rely heavily on Tibetian and overseas wool, which are produced in limited quantities. Nevertheless, the export potential of small ruminant products is encouraging and has become a source of employment for semiskilled and skilled workers.

LOCAL GENETIC RESOURCES OF SMALL RUMINANTS

Distribution of Local Breeds

The principal sheep breed is Barwal (63.1%) followed by Kage (20.7%), Lampuchhre (12.4%), and Bhanghlung breeds (3.8%) (Table 2). The existence of Jumli and Lohia has been cited by Epistein (1977) but has not yet been confirmed. Khari (lower hill goat) is the main goat breed (56.2%) followed by Terai (unconfirmed) (27.2%), Sinhal (15.6%), and Changra (Tibetian) (1.0%) (Table 2). Sixty-three percent of sheep, mainly Barwal and Banglung, and 7% of goats (Sinhal breed) are raised under the transhumance system of management.

Production Characteristics

The production potential of local breeds of sheep in terms of fibre and meat is very low, and the mortality rate of adults and lambs or kids is very high (Tables 3 and 4). The shortage of feed, hardships in the transhumance system of migration, mismanagement, uncontrolled breeding, parasites, and contagious diseases are the root cause of higher losses and low productivity.

The local Kage and Lampuchhre breeds of sheep and the Khari and Terai breeds of goats are quite prolific, but the mortality rate of lambs and kids is considerably high. Feed available from grazing on the outskirts of the village, fallow grazing, tree loppings, rice straw-chaff, some grains, etc., are not sufficient to meet the basic requirements of the animals.

FEED RESOURCES

Trans-Himalayan Region (Steppe)

The spiny dwarf shrubs dominate in the trans-himalayan region north of the Himalayan mountain range where the rainfall drops below 200 mm. Intense solar radiation without cloud interception and the continuous wind are responsible for a high evaportion rate, which limits the availability of moisture to the existing vegetation. Ground vegetation coverage is only 12-22%, and it consists of 60-80% Cargana sp., 15-35% Artemisia sp., 12% perennial species, and 3-4% other weeds (Shah 1979).

Most of the feed available in the region comes from grazing lands and shrubs (steppe); the sparse forest coverage provides only 6.5% and the cropland produces only 2.6% of total digestible nutrients (TDN) available, i.e., 812.3 x 10^3 t (Table 5). Forty-five percent of the TDN available from the steppe and shrubs, 55% from forest cover, and 90% of cropland products are assumed to be utilized because figures are difficult to obtain because of the rough terrain, inaccessibility,

Table 2. Ecological distribution of different breeds of sheep and goat in Nepal.

Ecological region	Altitude (m)	Climate	Sheep		Goat		Management system
			Breed	No. (%)	Breed	No. (%)	
Trans-Himalaya (behind Himalaya mountain range)	>2500	Temperate	Bhanglung (Tibetian)	30000 (3.8)	Changra (Pashmina, Cashmere)	47000 (1.0)	Sedentary and transhumance
High mountain	>2500	Temperate-alpine	Barwal (Jumli)	321863 (41.0)	Sinhal	100000 (2.0)	Transhumance
					Sinhal, high-hill goat	608425 (12.5)	Sedentary
Middle hill	1500-2500	Temperate	Barwal	173551 (22.1)	Sinhal	55000 (1.1)	Transhumance
Lower hill	300-1500	Subtropical	Kage	162253 (20.7)	Khari (local hill)	2744177 (56.2)	Sedentary
Terai	<300	Subtropical, tropical	Lampuchhre (Lohia)	97385	Terai (crossbreeds)	1327733 (27.2)	Sedentary moving
Total				785152		4882335	

Table 3. Production characteristics of local breeds of sheep.

	Bhanlung (Tibetians)[a]	Darwal[a]	Kage[b]	Lampuchhre
Birth weight (kg)	2.2	2.4	1.6	1.6-2.0
Adult weight (kg)	29.8	32.0	20.0	20.0-40.0
Lambing %	61.5	68.9	119.0	115.0
Lambing frequency per annum	1	1	1-2	1-2
Adult mortality (%)	35.5	25.6	15.0-20.0	15.0-20.0
Lamb mortality (%)	30.0-50.0	25.0-40.0	20.0-30.0	20.0-30.0
Wool production (kg)	0.8-1.0	0.9-1.2	0.32	0.3-0.5
Fibre diameter (μm)[c]	25-28 (14-70)	30 (14-64)	28-47 (10-144)	36-77.2
Kemp fibre[c]	12-13	68	20-81	52.3-67.9
Wool use	Carpets, rough garments	Radi (felt), rough covers	Medium quality covers and shawla	Rough mats

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[a] Karnali Sheep Farm, Department of Livestock Development and Animal Health (DLDAH), Kathmandu, Nepal, Annual Report 1978-79.

[b] Chitlang Sheep Farm, DLDAH, Kathmandu, Nepal, Annual Report 1982-83.

[c] Source: Epstein (1977).

and the remoteness of the grazing areas. The major share (93.9%) of TDN available from cropland products comes from crop residues, of which straw makes up 84.5%, brans, 15.3%, and cakes and others, 0.2%.

Table 4. Production characteristics of local breeds of goats.

	Changra (Pashmina) Cashmere	Sinhal	Khari	Terai
Birth weight (kg)	1.9-2.3	3.0	1.65	15-2.0
Adult weight (kg)	19.0-35.0	38.0	29.0	30.0-40.0
Pashmina production (g)	150-250	100	NA[a]	NA
Kidding %	60-100	100	175	157
Average litter size	1.0	1.0	1.8	1.5
First kidding age (months)	24-30	18-24	12-18	12-18
Milk production				
Per lactation (L)	NA	NA	34.0-58.6	87.1
Lactation days	NA	NA	106-139	126.4

Source: Pradhan and Garung (1985).
[a] NA, not available.

Surplus feed available in the region is utilized by the movement of animals from the midhills and high mountains of adjoining regions during the summer months. Furthermore, restriction on movement of animals from the region to the Tibetian plateau during winter will increase the pressure on feed resources and will create a feed deficit, which upsets the environmental balance in the region. Large ruminants, e.g., yaks, Chouri, cattle, etc., use up most of the available feed because the small ruminant population makes up only 10.5% of the total livestock units (LU) (Table 6).

Table 5. Animal feed production estimates for different ecological belts (t x 10^3).

	Terai			Lower hill			Middle hill		
		TDN			TDN			TDN	
	DMP	A	U	DMP	A	U	DMP	A	U
Grazing lands, shrubs									
Alpine meadows	-	-	-	-	-	-	530.2	255.2	-
Steppe	-	-	-	-	-	-	-	-	-
Open grazing	27.8	13.5	-	84.4	40.8	-	373.7	180.6	-
Shrubs	35.6	17.3	-	25.4	12.3	-	612.2	297.3	-
Wasteland, roadside grazing	9.3	4.4	-	9.4	4.5	-	119.4	57.3	-
Total	72.7	35.2	21.1	119.2	57.6	34.6	1635.5	790.4	474.2
	(1.3)[a]	(2.0)	(1.7)	(5.0)	(6.5)	(5.7)	(27.3)	(34.5)	(29.4)
Forest (open and full stock)	414.1	201.1	110.7	1011.8	491.4	270.3	1255.3	609.7	335.3
	(7.5)	(11.7)	(8.9)	(42.3)	(55.3)	(44.2)	(21.0)	(26.6)	(20.9)
Cropland (upland and lowland)									
Crop residue, by-products	4390.0	1160.0	-	1090.0	260.0	-	2400.0	540.0	-
Grass, weeds	430.0	240.0	-	90.0	50.0	-	360.0	200.0	-
Leaf and tree fodder	50.0	20.0	-	40.0	20.0	-	160.0	90.0	-
Fallow land grazing	200.0	70.0	-	40.0	10.0	-	170.0	60.0	-
Total	5070.0	1490.0	1117.5	1260.4	340.0	306.0	3090.0	890.0	801.0
	(91.2)	(86.3)	(89.4)	(52.7)	(38.2)	(50.1)	(51.7)	(38.9)	(49.7)
Total	5556.8	1726.4	1249.3	2391.0	889.0	610.9	5980.8	2290.1	1610.5

(continued)

Table 5. Concluded.

	High mountain			Trans-Himalaya			Total		
		TDN			TDN			TDN	
	DMP	A	U	DMP	A	U	DMP	A	U
Grazing lands, shrubs									
Alpine meadows	1590.7	765.5	-	1060.8	510.4	-	3181.7	1531.0	-
Steppe	-	-	-	22.1	11.0	-	22.1	11.0	-
Open grazing	144.7	69.9	-	216.5	104.6	-	847.1	409.4	-
Shrubs	90.4	43.9	-	183.8	89.3	-	947.4	460.1	-
Wasteland, roadside grazing	65.9	31.6	-	47.7	22.9	-	251.7	120.7	-
Total	1891.7	910.9	409.9	1530.9	738.2	332.2	5250.0	2532.3	1272.0
	(52.8)	(56.8)	(48.8)	(87.9)	(90.9)	(87.3)	(27.3)	(34.6)	(27.1)
Forest (open and full stock)	1142.4	554.8	305.1	108.6	52.8	29.0	3932.2	1909.9	1050.4
	(31.9)	(34.6)	(36.3)	(6.2)	(6.5)	(7.6)	(20.4)	(26.2)	(22.4)
Cropland (upland and lowland)									
Crop residue, by-products	480.0	106.0	-	100.0	20.0	-	8460.0	2086.0	-
Grass, weeds	50.0	27.0	-	2.0	1.0	-	932.0	518.0	-
Leaf and tree fodder	-	-	-	-	-	-	250.0	130.0	-
Fallow land grazing	18.0	6.0	-	1.0	0.3	-	429.0	146.0	-
Total	548.0	139.0	125.1	103.0	21.3	19.2	10071.0	2880.3	2368.8
	(15.3)	(18.6)	(14.9)	(5.9)	(2.6)	(5.1)	(52.7)	(39.3)	(50.5)
Total	3582.1	1604.7	840.1	1742.5	812.3	380.4	19253.2	7322.5	4691.2

Note: DMP, dry matter production; TDN, total digestible nutrients; A, available; U, utilized.

Source: Land Resource Mapping Project, September 1985; TDN availability (A) and utilization (U) data were calculated with the standard used by Rajbhandary and Shah (1981).

[a] Values in parentheses are percentages.

High Mountain Region

The major feed resources in the high mountain region come from the alpine meadows and shrubs, which contribute 56.8% of available TDN, i.e., 1604.7 x 10^3 t. Forest cover provides only 34.6% and cropland products makes up 186% of available TDN.

Alpine meadows are usually above 3600-5400 m elevation. The climax vegetation is mainly dwarf shrub land or juniper, rhododendron, and berberis of low stock value and short tussock grasses and shrubs with Festucae and Agropyron as the predominant species of high grazing value (Van Swinderen 1978). Forty-five percent of the grazing lands and shrubs, 55% of the forest cover, and 90% of cropland products only are utilized because of the rough terrain and climatic conditions. Of 106 x 10^3 t TDN available from crop residues, straws provide 83.8%, brans, 15.8%, and the rest, 0.4%.

The carrying capacity of the alpine peastures is about 1.42 LU/ha (Rajbhandary and Shah 1981). The animals spend about 4-5 months in this region during the summer, but small ruminants make up only 4% of the total LU in the region (Table 6).

Feed deficiency is 980.4 x 10^3 t, which is 53.9% of the TDN requirement (Table 6). The situation is further aggravated by the movement of animals from the middle hills to the high mountains. The deficit in feed supply is partially fulfilled by the movement of animals from the border areas to Tibet and to lower altitudes during the winter. The recent restriction on the movement of animals to the Tibetian region has further complicated the feed supply situation, especially in the border regions of Nepal.

Middle Hills

Forty-four percent of the total livestock population is concentrated in the midhills. High meadows, shrubs, communal grazing lands, and wastelands provide 790.4 x 10^3 t TDN, which is 34.5% of available TDN (2240.1 x 10^3 t). Forest cover provides 26.6% (609.7 x 10^3 t) and cropland provides 38.2% (890.0 x 10^3 t) of available TDN. Crop residues and byproducts provide nearly 60% (540 x 10^3 t) of TDN available from cropland products, grass and weeds, 22.5% (200 x 10^3 t), tree fodder, 10% (90 x 10^3 t), and fallowland, 6.7% (60 x 10^3 t).

Table 6. Ruminant feed balances in different ecological zones.

	Terai	Lower hills	Middle hills	High mountain	Trans-Himalaya	Total
Livestock						
Number[a]	3747814	1817016	6389700	2178972	730348	14863850
LU[b]	2609095	905532	4108501	1640088	287471	9550687
TDN required (t x 10^3)[c]	2896.1	1005.2	4560.4	1820.5	319.1	10601.3
TDN available (t x 10^3)[d]	1726.4	889.0	2290.1	1604.7	812.3	7322.5
TDN used (t x 10^3)[d]	1249.0 (72.4%)	610.0 (68.8%)	1610.5 (70.3%)	840.1 (52.4%)	380.4 (46.8%)	4691.2 (64.1%)
Balance						
Quality (t x 10^3)	-1169.7	-116.2	-2270.3	-215.8	493.2	-3278.8
% TDN required	40.4	11.5	49.8	11.9	154.6	30.9
TDN used (t x 10^3)	-1646.8	-395.2	-2949.9	-980.4	61.3	-5910.1
% TDN required	56.9	39.3	64.7	53.9	19.2	55.7

[a] Source: Department of Food and Agriculture Marketing Services, 1985.

[b] Livestock unit (LU) = 300 kg bullock. Cattle: adult, 1.0 LU; heifer, 0.67 LU; calf, 0.40 LU. Buffalo: adult, 1.5 LU; heifer, 1.0 LU; calf, 0.6 LU. Sheep and goats: adult, 0.1 LU; lambs and kids, 0.05 LU.

[c] Source: Land Resource Mapping Project, Nepal, September 1985.

[d] Source: Rajbhandary and Shah (1981).

Only 60% of grazing land and shrubs, 55% of forest areas, and 90% of cropland feed is utilized by the existing stock population. There is a sizeable deficit of 64.7% (2949.9 x 10^3 t) in the TDN requirement for the existing stock

(4660.4 x 10^3 t). The feed deficit is partially alleviated by the movement of animals to the high mountains.

Forest

Dependence on forest areas is always increasing with the cultivation pressure on the land. The carrying capacity of the forest is about 0.31 LU/ha (Rajbhandary and Shah 1981).

Fodder trees

Tree fodder and fallow land grazing contribute only 8.5% of TDN available in the region, but hold the most potential for generating extra feed through vigorous plantation of multipurpose fodder trees and the utilization of fallow land for leguminous fodder production. The estimated carrying capacity of fodder tree leaves and fallows are 0.08 LU/ha (Rajbhandary and Shah 1981).

Although the hill farmers recognize the importance of fodder trees, they have not received much attention by other groups because of the easy access to forest resources. Some of the most common fodder trees used by the farmers have been studied for their nutritive value (Table 7); however, these studies are far from complete and require some further investigation.

Crop residues

Of TDN available from crop residues and by-products (some 540 x 10^6 t), straws contribute 82.6%, brans, 16.7%, and cakes and others, 0.7%. Paddy and millet straws and maize stovers contribute 91.8% of TDN available from straws, whereas wheat straws provide only 1% of TDN.

Terrace risers and bunds

Terrace risers and bunds provide up to 20-24% of the total feed available from the cropland. The available surface area has not been fully utilized and it is a potential source for the production of good-quality feed (Rajbhandary and Shah 1981).

The present practice of scraping terrace walls should be discouraged and improved varieties of grasses and legumes should be introduced. Setaria anceps cv. Norko, Chloris guayana (Rhodes grass), Panicum maximum (green panic), and Paspalum dilatatum and Desmodium uncintum (silver leaf) have been successfully transplanted in terrace walls (Thapa 1985).

Table 7. Productivity and nutritive value of some commonly used fodder trees in Nepal.

Fodder tree species (local name) and characteristics[a]	EGMP[b] (t)	CP[c] (%)	Fodder tree leaves[d]				
			DM (%)	N (%)	Ash (%)	DMD (%)	OMD (%)
Artocarpus lakoocha (badahar); 500-1500; ST,T; F; 9-11; M	1.8-2.0	13.8-15.7	41	2.2	14.7	56.7	57.3
Litsea polyantha (kutmiro); 800-1500; ST; F; 6-7; FS	0.9-1.1	11.3-16.7	41	1.8	7.9	38.8	34.7
Bauhinia purpurea, *B. longfolia* (tanki); 600-1400; ST; F; 4-5; M	0.2-0.5	17.5	57	2.8	11.2	49.1	44.8
Bauhinia variegata (koiralo); 600-1400; ST; F,T; 4-5; M	0.3-0.6	11.9-19.0	52	1.9	9.4	34.9	29.3
Ficus lacor (kavro); 1000-1600; ST,T; F; 8-10; FS	1.6-1.8	11.3-13.8	47	1.8	11.6	46.9	43.8
Ficus cunia, *F. cordata* (khanaya); 1200-1600; ST; F; 7-8; FS	NA	10.6-11.9	44	1.7	18.5	55.5	54.2
Machilus glamblei, *M. odoralissina*; 800-2400; ST,T; F; 9-11; M	NA	10.9-11.3	43	1.8	4.4	42.2	39.6
Grewia oppositi folia (syalphusro); 1000-2400; ST,T; F; 9-11; M	NA	14.4	71	2.3	10.8	39.8	35.9
Albizzia mollis (rato siris); 600-1550; ST; F, FW; NA; NA	NA	17.5	50	2.8	6.9	40.1	37.3

(continued)

Table 7. Continued.

			Fodder tree leaves^{d}				
Fodder tree species (local name) and characteristics^{a}	EGMP^{b} (t)	CP^{c} (%)	DM (%)	N (%)	Ash (%)	DMD (%)	OMD (%)
Albizzia labbak (seto siris); 450-1400; ST; F, FW; NA; NA	NA	12.5	51	2.0	6.8	27.8	25.0
Bessia butyraceae (churi); 600-1200; ST; F, Fr; NA; S	NA	11.9	45	1.9	5.7	20.8	17.2
Bredia retusa (gayo); 600-1500; ST, T; F; NA; S	NA	10.6	53	1.7	7.4	40.4	27.9
Ficus nemoralis (dudhilo); 1300-1799; T; F; 8-10; FS	NA	10.6	46	1.7	9.6	55.0	53.2
Ficus roxburghii (nebharo); 1300-1900; T; F; 7-8; FS	NA	13.1-17.3	34	2.1	12.0	47.6	45.4
Brassiopsis hainla (seto chuletro); 1200-2300; ST, T; F; 8-10; FS	NA	12.5	42	2.0	11.0	65.4	62.5
Saurania nepalensis (gogan); 1500-2200; T; F; 8-10; M	NA	5.6-12.3	40	0.9	8.6	39.0	35.5
Prunus ceraloides (paiyu); 1200-2200; ST; F, FW, T; 6-8; F	NA	16.3	41	2.6	6.3	63.7	62.5
Quercus glauca, Q. lamellosa (phalate); 1800-3000; T; F, FW, T; 18-22; S	NA	8.6-11.9	66	1.9	4.1	32.4	33.3

(continued)

Table 7. Concluded.

Fodder tree species (local name) and characteristics[a]	EGMP[b] (t)	CP[c] (%)	Fodder tree leaves[d] DM (%)	N (%)	Ash (%)	DMD (%)	OMD (%)
Castepnosis hystrix (patale kalus); 1550-2250; T; F, FW, T; NA; NA	NA	12.5	44	2.0	3.8	34.0	32.2
Michelia champaea (champ); 1200-2700; ST, T; F, FW, T; NA; NA	NA	13.8	49	2.2	4.5	64.9	64.1
Salix spp. (bainsa); 1500-2500; T; F, FW; NA; NA	NA	18.8	52	3.0	10.2	55.6	51.2
Buddelia asiatica (bhimsen pate); 100-1700; ST, T; F; 5-6; FS	NA	19.8	NA	NA	NA	NA	NA

Note: Other commonly used fodder trees in the hills of Nepal include *Premna integrifolia* (gidari), *Ficus glaberrina* (pakhuri), and *Garuga pinnata* (dab dabe).

[a] After the species and local names of the fodder tree are the following characteristics: adaptive altitude (m); climate (ST, subtropical; T, tropical); use (F, fodder; Fr, fruit; T, timber; FW, firewood); production years; growth (FS, fast; M, medium; S, slow). NA, not available.

[b] EGMP, estimated green matter production; NA, not available. Source: Pradhan (1986).

[c] CP, crude protein.

[d] DM, dry matter; N, nitrogen; DMD, dry matter digestibility; OMD, organic matter digestibility; NA, not available. Source: Thapa (1985).

Fallow land

At present, fallow lands contribute only 6.7% of the total feed available from cropland; however, this land can contribute a significant amount of feed for the winter period if properly utilized. The major constraint for winter feed is moisture in the soil. Avena sativa (cv. Kent) and winter peas have been used for winter feed production. Screening of suitable species of grasses and legumes is necessary for introduction in the hills with low moisture content and temperature. Protection of the field from grazing animals is equally important. Relay and catch crops can produce significant amounts of feed, but they have not yet received much attention in the hilly regions of Nepal.

Lower Hills

Forest cover provides 55.3% (491.4 x 10^3 t), cropland accounts for 38.2% (340 x 10^3 t), and grazing land and shrubs provide only 6.5% (57.6 x 10^3 t) of TDN available in the region. Fifty-five percent, however, of available feed from the forest, 60% of grassland and shrubs, and 60% of cropland feeds are utilized by the animals. The feed deficit in the region is about 39.3% of TDN utilized. Crop residues and by-products provide significant amounts of feed (260 x 10^3 t), 29.2% of TDN available, of which straws contribute 75.0%, brans, 18.0%, cakes, 5.6%, and sugarcane tops and others, 1.4%.

Fodder trees around homesteads provide only 2.25% of TDN available because a major portion of the feed is coming from forest resources. Intense dependence of the forest is detrimental to the environment. The feed supply situation can be substantially improved with a tree fodder development program, optimum utilization of terrace bonds and walls, introduction of relay and catch crops, promotion of a silvipasture development program, and judicious utilization of crop residues and by-products.

Terai

In the terai region, the major source of feed supply is cropland products, which contribute 86.3% (1490 x 10^3 t) of TDN available (1726.4 x 10^3 t). Crop residues and by-products alone contribute 1160 x 10^3 t of TDN, which is 67.2% of TDN available. Leaf fodder, grass, and seeds from cultivated land and fallow land grazing provide 330 x 10^3 t of TDN, which is 19.1% of TDN available in the region. About 20% of the TDN available comes from open grazing, shrubs, wasteland, and roadside grazing. Seventy-five percent, however, of TDN available from croplands, 55% from the forest, and 60% from grazing lands and shrubs are available for the animals. The rest of the feed is either inaccessible because of dense forest or is used for other purposes, e.g., oil extraction, roofing, straw board, mat making, or burned for fuel by the farmers. Straws contribute 76.8% (870.4 x 10^3 t) of the TDN available from crop residues and by-products, whereas brans provide 20.2% (228.2 x 10^3 t) and cakes, sugarcane tops, and others account for 3% (33.7 x 10^3 t).

Despite the potential for fodder development in the terai region, there is a significant deficit of 56.9% (1646.8 x 10^3 t) of TDN required for the existing stock population because a sizeable proportion of feed is used for other purposes (Table 5). Also, the use of berseem (Trifolium alexandrinum L.) as a relay crop with rice in the terai region is promising, especially where there is a possibility of some irrigation. The surface area available in the bonds of rice field, used to some extent in the terai region, also holds promise for the introduction of tropical fodder legumes, such as pigeon pea, stylo, etc. Land left fallow during winter because of the shortage of water and manure is a potential source of production of winter feed, e.g., medics and vetches have shown some good results; however, systematic trials are necessary to identify the best species and to assess the productivity.

Fast-growing multipurpose tree fodders, e.g., Leucaena leucocephala, hold the most potential for introduction to wastelands, roadsides, community lands, and farm boundaries, but a community effort is needed to protect the growing plants from grazing animals. Large ruminants (68%) that dominate the region are used for plowing and as draft animals, and their manure is used on cultivated land.

In the overall context, the TDN requirement of 7705.2 x 10^3 t for the existing livestock population of 14.86 million is partially met by 2967.2 x 10^3 t of TDN available from different sources (Table 5). The deficiency equals 61.5% of the TDN requirement. A concerted effort is required, therefore, to launch a fodder development program and plans for the effective utilization of the available feed for the existing stock population to ensure that requirements necessary for a successful breed improvement program are met.

MANAGEMENT SYSTEM OF SMALL RUMINANTS

Transhumance System

Most of the small ruminants in the trans-Himalaya and high mountain regions are raised in the transhumance system of management because the feed available around the villages and the nearby grazing land is not sufficient to meet their daily needs and the cold winters are not conducive to the health of small ruminants. Only weak animals are left behind in the village. In the trans-Himalaya region, some border-area peoples take their animals to the north in the Tibetian plateau for grazing in winter and move back to the village in summer. On the summer migration route, the animals are either "camped" on fields, or the manure produced in the campsite and on pastureland is collected and brought down to the village to fertilize the fields and use as fuel in the winter. Movement of animals is sychronized with naked barley cultivation in the region.

The transhumance system of management is also practiced in the middle and high mountains south of the Himalaya mountain range. In their annual cycle of movement, the flocks reach the summer pasture below the tree line during April and May and reach the alpine pasture by July and stay there until the end of August or early September. The flocks utilize the alpine pastures for about 1.5 months and the summer pasture for 3.5 months and they reach village pastures by mid-October to coincide with the Hindu festival, Durja Puja. The animals are camped in the village pastures until the harvesting of summer crops, e.g., maize and rice, is over. The moving flocks are allowed to camp in the field at night after the harvest. For about 3 months, the flocks stay near the village depending upon the availability of feed from the cultivated land, terrace risers, wasteland, and forest grazing nearby.

The flocks slowly move down to the villages in the south, which are up to 4-5 days away from the home-base villages, and usually stay at the lower altitudes for about 3 months depending on the grazing status, availability of feed, standing crop, and temperature. With the rise in temperature in March, the flocks start to move quickly toward higher elevations to take advantage of the spring growth in the outskirts of the forest and alpine pasture. As the flocks move down to lower elevations, nearly 10.6% of the live weight of sheep, about 5 kg, is lost between the autumn and the winter season (Karki 1985). The animals don't make up their weight until they reach the summer pasture. Mating begins in late spring and summer as soon as they make up the lost weight. Nearly 78.8% of Barwal ewes and 68.5% of Sinhal goats were reported to have lambed during the period from November to February in western Nepal (Karki 1984).

During the annual cycle of movement under the transhumance system, lamb losses of 32.5-52.0% and an adult mortality rate of 19.7% have been reported in western Nepal (Pradhan 1979; Karki 1984). Major losses of up to 64% of the total loss were because of mismanagement, accidents, predators, and nutritional stress, whereas death caused by diseases and parasites accounted for only 36% (Karki 1985).

Stationary Management

In stationary management, the animals are housed in sheds at night and are taken to graze on the fallow land on shrubs and in the wasteland and forest close to the village during the daytime. During the monsoon season, with the standing crop in the field, the animals are stall-fed to control grazing in cultivated areas, and cut fodders from the village outskirts and forest areas are fed to housed animals. Fodders from tree loppings are used as feed during the late winter and dry summer period where there is no other grazing available in the village. In the terai districts, crop by-products, e.g., chaffed straws, brans, cakes, and sugarcane tops, are also fed to animals when there is a shortage of green feed around village homesteads.

The 6-7 h of grazing for small ruminants is inadequate, especially during the dry summer. Up to 20-30% of the kid and lamb mortality rate is caused by an inadequate, poor-quality feed supply and mismanagement by the farmers.

CONSTRAINTS

Feed Insufficiency

Feed insufficiency in terms of quantity and quality is the main problem affecting the development of small ruminants. The average per capita of cultivated land is only 1.8 ha, which is too small to maintain the large number of animals required for manure, draft power, and food production. The farmers have resorted to forest grazing and cutting to meet their needs. Furthermore, farmers have adopted the transhumance system of management to exploit the available herbage along the stock routes, i.e., forests and summer and alpine pastures. Major losses of up to 64% in the transhumance system of management result from the mismanagement of the flocks because of inexperienced shepherds.

Genetic Materials and Breeding System

Genetic resources of small ruminants are well-adapted to the environment but not productive enough for commercial exploitation. The aim of breeding, however, is survival, not production. Furthermore, the available genetic resources have not been quality assessed. The breeding system adopted by the farmers for small ruminants is often counterproductive. The best animals are often castrated and used as draft animals or sold for their meat without considering their use as future breeding stock. The farmers, however, are unaware of the need to select and breed the animals systematically to raise the quality of future stock and they must sell their animals on occasion to maintain their families. The use of exotic animals should be considered, however, to improve the quality and quantity of wool, milk, and meat, and the potential of local animals should also be studied to meet the requirements of export markets for carpets and woollen garments.

Wool produced from local sheep (about 670 t) is used only for making local floor coverings and clothing for the hill people. The cottage carpet industries, however, demand 2000-3000 t of Tibetan wool, which is partly met by imports from Tibet and overseas. Local sheep should be improved to produce suitable crossbred wool by the infusion of exotic strains. Rambouillet, Polwarth, Merino D'Arles, and Border Leicester breeds of sheep have been introduced. Although crossbreeds produce better wool, the survival of animals during transport is very poor and makes it unprofitable to raise improved animals under the existing management system. Identification and production of the most suitable breeds to improve local ruminants under the existing management system is a major long-term concern for the development of small ruminants in the country.

Similarly, milk and fibre production, e.g., mohair from small ruminants, have received limited attention because of development constraints. The farmers' priority to raise small ruminants for manure production and haulage, especially in the far-western districts of Nepal, does not comply with the national demand for meat, milk, and fibre. Price incentives and facilities are not enough to encourage a change to better wool, milk, and meat production. Alternative sources of haulage and manure will be necessary to channel the small ruminant production system toward producing food for human consumption and fibre.

Poisonous Plants and Predators

Poisonous plants often account for a loss of up to 10-15% of lambs each year in the moving flock, especially during the spring season near the summer pasture. Experienced shepherds recognize the poisonous plants and divert the animals, but the inexperienced shepherds have no means to avoid the problem and are not familiar with any local antidotes. The ability to identify and screen poisonous plants along the stock route and a knowledge of the appropriate antidotes are essential. Wild animals, e.g., leopards, wolves, and foxes, especially near the National Wildlife Park, are also a serious menace and cause considerable losses (10-20%) in the flock each year. This has become the most serious problem in the western region of Nepal.

Marketing Outlets/Channels

Marketing outlets for small ruminant products consist of the villages that are along the annual migration routes, and they are miles away from the main marketing centres of the south. Farmers, although they have few animals or products to sell, have no alternative but to sell in the villages during festivals, e.g., Durga Puja. Furthermore, the price difference between the villages and marketing centres is not great enough to warrant taking their animals to the south across the mountains and valleys.

The distance between production areas and the main marketing centres makes the cost of transportation too high and the terrain makes moving products difficult. Furthermore, the cottage industries receive raw materials from Tibet and overseas at reasonable prices, which does not encourage local production. Development programs to produce more good-quality fibre, milk, and meat must be linked up with the cottage industries to utilize the available products.

Animal Health Coverage/Services

The available animal health services are not sufficient to meet the needs of villages scattered over the mountains. The farmers must resort to local herbal medications to combat contagious diseases, e.g., foot rot, foot-and-mouth disease, enterotoxaemia, blackquarter, and parasites. Advisory services supplied by the existing organizations cannot reach the remote villages. The government has launched an extensive village animal health worker training program to provide basic animal health services in the villages; however, the training does not fully prepare the health workers to meet the needs of the village. Furthermore, a lack of career opportunities does not attract villagers to the job.

Social Factor

The social prestige of the local communities of the hills and terai regions is linked with the number of animals kept, and this is often a drawback when culling is necessary to dispose of unproductive animals and support the development program to proliferate productive animals for better economic returns. It creates an extra stress on the already scarce feed resources.

Skilled Manpower

Mismanagement of animals often results from employing unskilled labour. Incentives to attract competent shepherds to an often hazardous profession are inadequate. Furthermore, the absentee owners cannot supervise the animals properly. The shortage of trained medium-level technicians also makes it even more difficult to conduct programs in the remote regions of Nepal.

Heavy Taxes

Taxes imposed by local authorities, e.g., panchayat, as grazing fees are often heavy and adversely affect the animal production system in the hills.

INNOVATIVE CHANGES

The present estimate of the carrying capacity of 1.42 LU can be increased to 1.77 LU, with the adoption of rotational grazing and opening of tracks to inaccessible pasturelands; clearing of unwanted bushes and shrubs, boulders, and stones to allow regeneration of palatable species; and construction of watering points at convenient points to avoid overgrazing (Rajbhandary and Shah 1981). Excess feed should be converted into hay and either stored in a convenient place or transported to the nearest village as a buffer stock for winter shortage.

Most of the villages of small ruminant owners are located in the middle and lower hills. It is essential to develop feed resources in the village itself and adopt improved techniques to enrich the herbage. Wasteland, community land, village track sides, fallow lands, and open lands should be converted into feed resource pools with a major effort on growing more fodder through development campaigns. Catch crops and relay crops should also be introduced wherever feasible. Excess fodder should be stored as hay or silage, whichever is practicable.

The proper utilization and enrichment of agricultural by-products, e.g., straws, brans, and cakes, with suitable chaffing technology, liming, and urea treatment needs to be propagated for its best use. A campaign to develop multipurpose tree fodders and shrubs as winter fodder banks along the boundaries of cultivated land and terrace banks is also very important. The surface area available in terrace risers, banks, walls, etc., should be harnessed for use with the available technology in harmony with crop production and further development of the technology.

Silvipasture development can increase the productivity of quality fodder from the available land. The inclusion of perennial forage legumes under forest and fodder tree plantations will produce significant amounts of feed for animals and prevent soil erosion, improve soil fertility, and provide nutrients for the companion trees. Promising species of grasses and legumes for the lower hills and terai are *Stylosanthes guianensis*, *Desmodium intortum*, *Setaria anceps*, and *Paspalum* spp., and, for the midhills, *Dactylis glomerata* and *Trifolium repens*; however, full-scale investigation of suitable grasses and legumes for silvipasture development is highly warranted.

The terai region (subtropical belt) has the best climate for the production of subtropical fodders, suitable catch crops, and relay crops and, in association with paddy, wheat, and maize, should be initiated vigorously in the region. Berseem (*T. alexandrium*) cultivation as a relay crop to rice is catching wherever there is ample moisture in winter. Some vetch and medic species are suitable for the dryer parts of the terai, but further investigation is necessary. Proper utilization of crop residues is of immense importance and needs to be enriched by chaffing, liming, or urea treatment and formulated with cheap, balanced feed using local ingredients.

Because the majority of animals are grazed in the adjoining forest, the resources are being depleted; therefore, it is essential to grow tree fodders and shrubs on roadsides, wastelands, and community lands for common use with ample protection from grazing animals. Terrace banks and fallow lands have be exploited equally with suitable fodder species for the best use of lands for animals.

The transhumance system makes the best use of available feed resources. The system, however, has experienced tremendous losses of young ruminants from plant poisoning, predators, mismanagement, migratory stress, etc. Furthermore, the crossbreeds of small ruminants, although offering greater potential to produce fibre, meat, and milk, have failed to withstand the migratory stress and continue production. It has become necessary to stop the migration of crossbreeds and better-producing animals and let the other lower-quality animals move as usual, which disrupts the age-old migratory tradition in the hills.

In the far-western regions of Nepal, the sturdiest of small ruminants are selected and castrated for haulage purposes. This practice has caused the quality of the breed to deteriorate substantially in this region compared with the animals of the western and central regions. It is essential, therefore, to promote the use of mules in the lower and middle hills and Jhopas in high mountains as beasts of burden, which will release the small ruminants for production purposes. However, advisory services and logistical support available for the small ruminant production system are grossly inadequate and need improvement.

A link between cottage industries and production is highly desirable so that the available products may be put to better use. Small farmer cooperatives should be initiated to supply raw materials to the woollen and carpet cottage industries. Establishment of credit agencies in the major villages and towns is equally important for the credit flow to small ruminant raisers.

Efforts of government and government-affiliated agencies are not enough to ensure the preservation of the forest and grazing lands of villages. Mass participation of the village people is very important for communal land development, feed production, and the control of grazing and stall feeding.

CRITICAL LIMITATIONS

The shortage of land for food grain and animal feed production is the most critical limitation to small ruminant development in Nepal. Per capita cultivated land is only 1.8 ha, but 0.6 ha of all types of land, including cropland, grazing forest, and fallow land, is available for one livestock unit (LU), which is grossly inadequate for the present stock. Feed deficits for the total livestock population of 14.86 million is 5910.1 x 10^3 t of TDN, which is 55.7% of the TDN requirement, although only 64.1% of the TDN available is utilized.

Small ruminants under the transhumance system are further handicapped by the unavailability of crop by-products in the lower hills during periods of nutritional stress in the winter. At this time, the flocks are away from their home villages and the farmer cannot afford to purchase feed.

A large number of animals are kept for manure and draft purposes. The productive animals are only 10-20% of the total stock population. A high stock density has placed an extra burden of the feed supply and the productive animals don't receive an adequate share to meet their basic requirements. Alternative sources of manure and draft power will be necessary before the farmers will be able to cut down the number of animals carried per household.

Shortages of feed in the village grazing and cultivated areas have forced the farmers to rely heavily on forest resources and adopt the transhumance system of migration to utilize the available feed resources; however, losses of animals under the transhumance system are too high to make it an economically viable system. The stress of migration makes it very difficult for animals to both survive and produce. It has become a necessity to keep the improved and productive animals in the village and produce enough feed to meet their requirements for the whole year.

POTENTIAL OF SMALL RUMINANT DEVELOPMENT

Small ruminants are very important in Nepal because farm holdings are very small. The present share of 22.0% of total meat production from small ruminants could easily be increased to 50% if a massive fodder development program and crop by-product utilization program was launched to recover the losses in the present production system. Improvement in the environment for better production and marketing facilities is essential.

The production potential of local genetic resources has not been fully realized as local breeds of small ruminants of the lower hill and terai regions have good prolificacy and can be exploited for meat, milk, and fibre production. Small ruminants of the high mountains are less productive but are adapted to the transhumance production system. If the feed and management system can be improved by an appropriate farmer-training program, production of local animals could be increased.

Potential of milk production from small ruminants has received less attention because feed shortages have restricted the production potential of small ruminants. There is a significant variation in milk production potential of small ruminants that must be studied carefully.

A small country like Nepal can make the best use of milch breeds of small ruminants to improve the nutritional standard of the people. Importation of milch breeds of small ruminants from the neighbouring countries and overseas can help to produce crossbreeds for milk production.

The market demand for carpets and fine wool can be produced to some extent with the infusion of suitable breeds from overseas and an overall change in the management system of small ruminants provided there is a price incentive and market facilities. The need for 2000-3000 t of raw wool for industries, however, cannot be met by local produce because the small population of sheep is scattered all over the country. Although Pashmina fetch a better price in the international market, its production is limited. The changra (Pashmina) goat population of the trans-himalaya region is quite small. Feed shortages and climatic limitations in the region restrict any efforts to increase the production potential. Furthermore, the production potential of changra goats in Nepal has not been studied in detail.

There is great potential in developing local goats of the far-western regions of Nepal for mohair production with suitable vegetation and low precipitation. The development of multipurpose goats for meat, milk, and fibre is becoming a necessity for the intensive development of smallholdings in hill environments of Nepal.

Joint studies on local genetic resources and improved technologies for production exchange of genetic materials, information, and expertise in the South and Southeast Asian region will give greater impetus to the development of more productive small ruminants in Nepal.

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INTEGRATION OF SMALL RUMINANTS AND TREE CROPPING IN SOUTH INDIA

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Abstract *This paper discusses various features of small ruminants (sheep and goats) in the four states of south India: Kerala, Karnataka, Tamil Nadu, and Andhra Pradesh. From 1972 to 1982, while the population of sheep remained more or less stable, the goat population increased by about 30%. Out of about* 13.3×10^6 *sheep and goats slaughtered in India, the southern states accounted for more than 39%.*

The traditional system of rearing through migration declined considerably because of fewer areas being used for grazing, more intensive cultivation, or a reduction in migratory habits and the popularity of keeping fewer animals, particularly in the poorer sections of the society. There is considerable scope for the planned exploitation of the existing tree crops and herbage. The estimated herbage in Kerala is greater than 2.1×10^6*. There is considerable potential for the interculture of fodder crops in plantation and other cash crops. The productivity of meat and milk can also be considerably improved through genetic manipulation and scientific management. A comprehensive approach is needed to face the challenges in the development of small ruminant production.*

India can be conveniently divided into two geological areas: the peninsular region of south India, comprising the Deccan plateau and its adjuncts, and the extrapeninsular region of north India, comprising the Himalayan mountains and the extensive Indogangetic plain. South India has two principal mountain ranges: the western ghats, which cover the eastern fringe of the west coast plains and catch the full force of monsoon winds, thus precipitating heavy rains on the west coat, and the eastern ghats, irregularly scattered over the east coast of India and forming the boundary of the east coast plains.

Because of the unique geographic situation of south India, there is a rich and varied vegetation, typically tropical in nature. Two broad agroclimatic zones can be identified: the wet undulating coastal region dominated by tree crops and the fairly long coastal plains dominated by cereal crops. The wet zone covers the state of Kerala, the western part of the state of Karnataka, and the southern part of Tamil Nadu. The dry zone is composed of a major portion of Tamil Nadu, Karnataka, and Andhra Pradesh. In this paper, the status of small ruminants (sheep and goats) in relation to tree crops in the four southern states of Kerala, Karnataka, Tamil Nadu, and Andhra Pradesh will be discussed, with special emphasis on the situation in Kerala.

IMPORTANCE OF SMALL RUMINANTS

In south India, the sheep and goat populations account for 43 and 24%, respectively, of the total number of sheep and goats in the country. The goat population is denser in the wet zone, particularly on the western coast; most sheep are found in the dry regions. The two species contribute considerably to meat production in India and the share of total meat produced is presented in Table 1. From a total of 13.24×10^6 slaughtered animals during 1977-78, the four southern states accounted for 5.15×10^6 or about 39%. At present, the per capita availability of meat is only 25 g compared with a per capita nutritional requirement of 40 g. To meet this demand, small ruminants must play a major role.

On the west coast, milk production is the most important function of goats. In Kerala, nearly 8% of the total milk produced, i.e., 1.08×10^6 t (1984), is obtained from goats. Sample surveys conducted in other states do not give any values for milk production by goats, but perhaps their contribution to state milk production is negligible compared with that of cattle and buffalo. From experiments conducted in Kerala, it is evident that productivity of native goats could be more than doubled by the introduction of cross breeding with the Saanen breeds (Mukundan et al. 1983).

In addition to being a highly palatable and nutritious protein food, with their wool, sheep provide warm and protective clothing. In this region, especially in the coastal

Table 1. Number of small ruminants slaughtered and meat produced in south India, 1977-78.

State	Sheep			Goat			Total meat from livestock (t x 10^3)
	No. slaughtered (x 10^3)	Meat production (t x 10^3)	% of total meat	No. slaughtered (x 10^3)	Meat production (t x 10^3)	% of total meat	
Kerala	77	0.82	2.7	209	3.06	10.0	30.71
Karnataka	418	4.23	33.6	266	2.90	23.1	12.58
Tamil Nadu	1090	11.84	37.4	1068	11.15	35.2	31.64
Andhra Pradesh	1085	15.97	31.4	934	14.60	28.7	50.92
South India	2670	32.86	26.1	2477	31.71	25.2	125.85
All India	7876	81.30	25.4	5362	63.30	19.8	319.68

Source: Statistical Bulletin, Animal Husbandry Department, Government of Tamil Nadu, India.

areas, half of the sheep produce no wool and the rest produce extremely coarse, hairy, and coloured fleece used in the production of coarse sheets to the benefit of the lower income groups. In terms of enriching the soil, goat manure is twice as rich in plant nutrients as cow dung.

Sheep and goats earn foreign exchange primarily through the export of skins. India exported 13 t of raw sheep and lamb skins and 5824 t of processed sheep and goat skins in addition to by-products during 1979-80 (Government of India 1980).

POPULATION CHANGES

Changes in sheep and goat populations in the four states based on quinquennial censuses of 1972, 1977, and 1982 are noted in Table 2. The sheep population has remained fairly constant from 1972 to 1982. The situation regarding goats, however, shows a steady increase of 28% over the same period. Except in Kerala, sheep outnumber goats in all the states of south India. Considering the overall population in south India, the populations of sheep and goats seem to be almost equal.

The density of sheep in south India is about 28 sheep/km^2 and the goat density is about 27 goats/km^2, showing little difference between the two species. For the rest of India, however, there is an obvious difference in small ruminant densities, with 13 sheep/km^2 and 22 goats/km^2. More than 90% of all sheep and goats are found in rural areas.

The sex ratio based on the number of males for every 1000 females decreased in both the sheep and goat populations with increasing age of the animals. Perhaps the phenomenon is comparable to that noticed in other livestock; however, the overall sex ratios in this region are 382:1000 and 408:1000 for sheep and goats, respectively. The higher ratio in goats may be because of a deviation in management noticed in the case of goats when they were kept for milking and the higher number of breeding males per unit of breeding females. For breeding purposes, the ratio is more than satisfactory. The increase in goat population, therefore, may be because of its greater prolificacy through the frequency of twins and triplets as compared with sheep.

In this region, there are 14 recognized sheep breeds and 3 recognized goat breeds. The sheep breeds include Deccani,

Table 2. Population changes in small ruminants of south India, 1972-1982.

	Kerala			Karnataka			Tamil Nadu			Andhra Pradesh		
	1972	1977	1982	1972	1977	1982	1972	1977	1982	1972	1977	1982
Sheep												
Total (x 10^3)	10	3	7	4662	4536	4792	5393	5289	5537	8251	7064	7507
Density	0.26	0.08	0.18	24.3	23.6	25.0	41.5	40.7	42.6	29.8	25.5	27.1
Goats												
Total (x 10^3)	1468	1683	2004	3726	3388	4546	3954	4202	5246	4308	4364	5534
Density	37.6	43.2	51.4	19.4	17.6	23.7	30.4	32.3	40.4	15.6	15.8	20.0
Total sheep and goats (x 10^3)	1478	1686	2011	8388	7924	9338	9347	9491	10783	12559	11428	13041
Total livestock (x 10^3)	4936	5319	5644	21965	21800	26148	23433	24146	26186	32786	31472	35736
% of sheep to total livestock	0.2	0.05	0.12	21.2	20.8	18.3	23.0	21.9	21.1	25.2	22.4	21.0
% of goats to total livestock	29.7	31.6	35.5	17.0	15.5	17.4	16.9	17.4	20.6	13.1	13.9	15.5

Source: Thirteenth Quinquennial Livestock Census, 1982, Animal Husbandry Department, Governments of Kerala, Karnataka, Tamil Nadu, and Andhra Pradesh, India.

Nellore, Bellary, Hassan, Mandya, Mecheri, Kilakarsal, Vempu, Coimbatore, Nilgiris, Ramnad white, Madras red, Tiruchy black, and Kenguri; the important goat breeds are Osmanabadi, Kannai adu, and Malabari. Origin (home tract), population size, flock size, growth, reproduction and production parameters, and physical confirmation of these breeds have been documented by Acharya and Bhat (1984).

REARING OF SMALL RUMINANTS

As mentioned earlier, one of the objectives of sheep and goat rearing in this region is to produce meat economically. In certain parts of south India, sheep and goats are maintained for wool and milk production, respectively. Depending upon the objectives, different systems of management are followed by the sheep and goat owners.

Sheep are more used to browsing, whereas goats thrive mainly on tree leaves. Perhaps the locational differences might have encouraged these preferences. As tree crops are less dense in the semi-arid areas and browsing facilities are limited in area and duration, the migration of flocks was common.

Most sheep are reared under the "nomadic" system of management because sheep-rearing areas are mostly semi-arid and feed resources are exhausted very early after the cessation of monsoon rains. In the nomadic system, the migration of sheep for grazing can be classified as interstate nomadic or semimigratory. Shepherds owning interstate nomadic flocks may be either landless or those who have been hired by the larger flock owners. The former group of shepherds must adopt the nomadic system because they have no landholdings of their own; the latter group consists of traditional shepherds who prefer to migrate from place to place looking for available grazing land. During the agricultural off-season, sheep are herded together at night in the fields, the manure helping to fertilize the fields. They are penned by using bamboo or thorn fencing and are moved from one field to another.

Income from the sheep in this system comes from the sale of surplus sheep or from the manure deposited on the cultivable land belonging to large-scale farmers in the camping areas. In semimigration, the shepherds follow definite grazing patterns for about 5 months each year during the summer until the onset of the rainy season. Rituals are performed to fix the starting and ending dates of migration and to keep the flock free from diseases during the course of their migration. The migratory system helps the sheep owners to generate income without any personal investment. Shepherds are paid in kind with food grains for the services rendered to the farmers by way of folding the sheep in the fields for manure.

Sheep are housed during the monsoon season and during the winter. In the summer, the animals are grazed in the early hours of the morning. During the day, they are sheltered under mango trees and other shade-tree species. In well-organized farms maintained by the government and a few wealthy farmers, sheds with proper ventilation and sanitary conditions are provided.

Sheep graze extensively on the available forest lands, hill slopes, waysides, riverbeds, and on stubbles in the postharvest fields. Individual sheep holdings range from 5 to 100 head under the flock system. The rams are always grouped with the ewes at a ratio of 1:10, respectively. Most breeds can breed all year round; but breeding is done seasonally because of the migratory nature of the flock.

The management practices for goats in south India are similar to those of sheep, except that goats are more confined than sheep. Because goats are kept in the wet regions, they need dry housing; therefore, sheds on stilts are erected adjacent to the owner's house with an extension of the roof. The floor is elevated about 1-1.5 m to facilitate cleaning. Another floor underneath the slatted one is provided; it is here that the urine and dung are collected. Palm leaves or tiles are used as roofing materials and bamboo or wooden slates are used for flooring. Facilities for feeding concentrates and roughage are also provided in the goat house. In drier parts of this region, ground level houses are constructed by a few organized farmers. This type of housing is about 2-3 m high at the front and 1-1.5 m high at the back. Usually, a thatched roof with mud flooring is common to these houses.

In the semi-intensive system, goats are tethered in a different place each day so that a variety of plants are available. It is a convenient method because it offers better control and requires minimal labour and utilization of the local forage. Often, two to five goats are maintained by households, particularly as a supplementary occupation for the women.

The major portion of the goat population is found in the rural areas and raised by the poorer socioeconomic sections of the community. Most of the flocks consist of two to five goats grazed on marginal lands and consuming agricultural by-products and kitchen waste. No concentrate feeding is generally practiced except when the animals are in milk. At kidding, the female is given the necessary attention. In this system, all the owners may not keep their own bucks, so the females are taken to breeding bucks maintained separately by certain farmers.

CROPPING SYSTEM

The physiographical features of south India favour the growth of different types of irrigated and nonirrigated tree crops. In India, tree crops occupy about 2% of the area cultivated under all crops and account for sizeable export earnings. Crops such as tea, coffee, cashew nuts, etc., contribute to exports, whereas crops such as coconut, arecanut, rubber, cocoa, fruit trees, etc., cater to internal consumption, i.e., the domestic and industrial markets.

Tree crops, in general, afford considerable scope for improving returns per unit area, time, and inputs as compared with annuals. In intermixed and multistoried cropping and mixed farming, efficient soil harvesting, solar energy, and air space utilization are possible with tree crops and, unlike annuals, most of the tree crops remain in the field for many years. Their physiological adaptability is much better than annuals, so much so that crop losses are minimal. By using the mixed and intercropping pattern, the risk can be further minimized. Tree crops, therefore, with their potential for intensive management, represent one of the best means to stabilize income (Nelliat 1978). Important tree crops and areas in hectares under each tree crop, of Kerala, Karnataka, and Tamil Nadu are presented in Table 3.

The literature shows that no systematic efforts have been made to assess the extent of herbage produced interspaced among tree crops, under natural conditions. A preliminary sample survey, however, was conducted by the authors on the production of natural herbage in a lean season under various tree crops grown on the Kerala Agricultural University farms. It is estimated that 1520-2200 kg/ha of natural herbage is grown producing on average 300-450 kg dry matter (DM)/ha. The tree

Table 3. Areas of important tree crops in south India (ha x 10^3).

Crop	Kerala	Karnataka	Tamil Nadu
Cashew	141.277	55.028	60.828
Jack	61.918	8.099	2.061
Mango	62.574	53.351	37.073
Coconut	662.657	295.651	61.016
Rubber	215.474	NA	12.534
Arecanut	60.816	73.663	NA
Pepper	108.073	7.576	0.491
Total	1312.789	49.368	174.003

Note: NA, not available.

Source: Statistics for Planning, Directorate of Economics and Statistics, Governments of Kerala and of Karnataka, India. Season and Crop Reports, Department of Statistics, Government of Tamil Nadu, India.

crops included in the survey and estimated total production in Kerala are given in Table 4.

Bavappa (1974) reported that 23% of soil on an area basis alone is being effectively used by the coconut roots in a unit area of plantation. For depth, 80% of the roots are confined to a 31-120 cm layer of the soil. For the canopy, the light utilization by coconut comes to only about 50%. These findings indicate that both the soil and the aboveground space in a coconut plantation can support a number of other crops. Based on findings from the studies mentioned, experiments conducted at the Central Plantation Crops Research Institute, Kasaragode, showed that the fodder grasses guatemala (Tripsacum laxum),

Table 4. Estimation of natural herbage production in Kerala.

Crop	Area of Kerala state (ha)	Herbage production (kg/ha)	Total herbage production (t)
Cashew	141277	2200	310809.4
Pepper	108073	2820	304765.9
Mango	62574	2200	137706.8
Rubber	215474	1620	349067.9
Homestead (marginal 1 ha)	687400	1520	1044848.0
Total	-	-	2147198.0

hybrid napier (var. NB 21), and guinea grass (*Panicum maximum*) annually yield 50-60 t/ha of green fodder under coconut shade and the legumes Brazilian lucerne (*Stylosanthes gracilis*) and cowpea (*Vigna unguiculata*) produce about 30 t/ha annually. At a feeding rate of 30-35 kg of green fodder to one animal per day, four milch cattle can be maintained on 1 ha of a coconut plantation (Nair et al. 1976). On an animal unit basis, this is equivalent to 24-28 small ruminants/ha. This study indicates a significant potential for growing fodder artificially as well as naturally to overcome fodder shortage periods caused by the diminishing grazing-pasture lands.

Tree crops provide feeds for livestock through agricultural by-products. If these products are properly collected and processed, they will replace costly concentrates to a great extent. Some of the agricultural by-products available from the tree crops of this region are coconut cake, rubber seed cake, mango seed kernel, spent coffee, tamarind seed, and mango and jack fruit skins. The chemical composition and nutritive value of these by-products are reported by Sampath (1984).

PRODUCTIVITY LIMITATIONS AND CONSTRAINTS

A low level of productivity is caused mainly by the inadequate provision of feed and attention to nutritional requirements, lack of efficient scientific management, diseases and pests, and poor genetic potential as a result of the absence of a selection and breeding program and very little research support. Added to these constraints are difficulties encountered with marketing and the full utilization of products and the failure to exploit the full potential use of animal by-products.

Small ruminant production remains in the hands of low-income, landless, or small-scale, subsistence farmers who either do not own any land or possess low-return holdings, resulting in small ruminants feeding only on natural vegetation and crop stubbles supplemented with tree loppings. Intensive agricultural production has led to the depletion of grazing lands together with an increase in the number of the animals, which has resulted in an increase in the density of livestock per unit of grazing area.

The problem of adequately meeting the nutritional requirements of an estimated 36 x 10^6 small ruminants is a challenge in itself. Singh and Singh (1983) reviewed the feed situation and reported that about 6.5 x 10^6 ha of land will have to be brought under developed pastures, consisting of grasses and legumes, to meet the total dry matter requirement of about 13 x 10^6 t to maintain the total sheep population of the country. In relation to the entire country, small ruminants in south India face intense stress because of the higher density of livestock and more areas under cultivation. There is no possibility of sparing any cultivable land for goat and sheep grazing.

In certain parts of Tamil Nadu, specifically Nilgiris, toxic pasture weeds are thought to seriously affect the health of sheep (Pachiappan et al. 1983). Hepatitis, gastroenteritis, and nervous disorders are the complaints commonly attributed to toxic weeds, which include *Echium plantagineum*, *Cycas* spp., *Euphorbia*, *Delphinium*, *Lobelia inflata*, and *Oxalis cernua*. Thorny weeds, such as *Ulex europueus*, *Rubus moulueanus*, and *Rubus race-mousus*, pose health risks too; they also leave vegetable burrs on the wool. Another group of weeds called "killer weeds," including *Juncas*, *Erogrostis curivella*, and *Cyprus* spp., are fatal when their tender shoots are eaten. In Nilgiris, Bracken fern, canary grasses, perennial rye grasses, panic grasses, and Kikiyu grasses cause various kinds of disorders in the animal.

The intensive afforestation program has eliminated the grazing areas necessary for the migratory sheep and goats, thus disturbing management practices followed for centuries. The reduction in pasture lands is caused by urbanization and the ever-increasing housing needs of the human population.

Land left for grazing has been overgrazed, causing a depletion of vegetation and, consequently, a seriously reduced carrying capacity. The usually low and erratic rainfall together with extreme ambient temperatures and the use of water resources for agricultural irrigation purposes are the inherent physical hazards making efficient land use a difficult proposition in the semi-arid regions. Sheep grazing has been the traditional occupation of many families and with the scope for economic advancement, the number of persons available to carry out this traditional occupation is rapidly declining. Instead, the system of rearing only a few goats or sheep by households is becoming more popular.

The general health of the animals is low most of the time and poor health has a direct bearing on the animal's performance, output, and life span. In this country, several devastating diseases, such as pox, enterotoxemia, pasteurellosis, anthrax, rinderpest, and foot-and-mouth disease, are widespread. There are also several chronic diseases, such as Johne's disease, brucellosis, parasitic infestations, that hamper the productivity of the animals. Also, several new diseases, such as bluetongue, pare influenza-3 infection, mycoplasmosis, chlamydosis, etc., are beginning to threaten the sheep industry. In both lambs and kids, pneumonia and enteritis are the main causes of death. The introduction of exotic genes increased the mortality rate of young animals.

No large-scale, genetic improvement program has been undertaken by the government in small ruminant production. The main constraints are imperfections in the artificial insemination techniques and maintenance of exotic germ plasm. No attempts have been made to improve the native breeds of sheep and goats through selection.

INNOVATIVE CHANGES AFFECTING THE PRODUCTION SYSTEM

To increase the productivity of small ruminants, the existing constraints should be removed and new technological changes should be introduced. A decision should be made on the priority of constraints to be removed depending upon the availability of labour, material, and money.

Because there is hardly any further scope for expansion as a result of the pressure caused by intensive crop production, the extensive system of management should be gradually replaced by the intensive or semi-intensive system of management. Areas in the semi-arid zone that cannot support cattle and buffalo will have to be identified and could be utilized for small ruminant production with low investment.

Legislation protecting and encouraging crop and cattle production has already been enacted. Rural pasture lands, therefore, should consequently be protected through legislation and forest lands should be available for controlled grazing of small animals. Rural pasture land should be improved through reseeding with nutritious, perennial, and high-yielding grasses and legumes.

Because they are efficient converters of coarse fodder, sheep and goats should be fed with fodders that contain a major portion of such unconventional ingredients as tree leaves, bushes, and harmless weeds growing under tree crops. In south India, tree leaves of *Acacia* spp., *Syzyguim* spp., *Batula* spp., *Cellis* spp., *Albezia* spp., *Sesbania grandiflora*, Babul, Murungai, Mango, and *Leucaena leucocephala* are widely used as fodder supplements to small ruminants (Pachiappan et al. 1983).

An approximate balance between livestock numbers and fodder resources could be achieved by increasing the large-scale plantation of fodder trees and their planned management. These trees can be grown in pasture lands, waste lands, on riverbanks and bunds of ponds, canals, and agricultural fields. A system should be developed to lop the trees periodically without endangering them but also to ensure that future demand will be met. Natural herbage growing under plantation tree crops should be collected and conserved in the form of hay. Wherever possible, controlled grazing underneath tree canopies should be practiced on a rotational basis. Fodder cultivation under plantation crops should be encouraged by the government. Some tree leaves contain tannin and mimosin, which are harmful to animal health and productivity. A suitable processing method must be developed to ensure safe consumption and maximum utilization of tree leaves.

Efforts to identify and utilize agricultural by-products should be intensified. Production and consumption of a balanced livestock feed mixture based on maximum use of by-products should be developed in a coordinated manner. Animal health facilities should also be strengthened and action should be taken to develop vaccines against emerging diseases and to protect the animals from ecto- and endoparasitic infestation.

Large-scale government farms should be strengthened to produce sufficient numbers of superior breeding rams and bucks. At the same time, a system should be developed to produce breeding males other than those on the government farm. Incentives should be considered to encourage large-scale operators to increase the number of pure and exotic breeds to raise the general quality of all breeds. These crossbreeds could then be sold locally at competitive prices. Steps should also be taken to preserve the rapidly disappearing, valuable breeds of Mandya and Nilgiris sheep. Artificial cattle insemination facilities should be developed and frozen semen techniques for sheep and goats should also be developed and popularized.

Cooperative societies should be formed to take care of all aspects of husbandry practices and product marketing. This system has already been initiated on a small scale in some states. Well-designed slaughter houses should be established to minimize waste and maximize productivity per animal. Long-distance travel should be discouraged to avoid losses caused by death and weight loss. The sheep and goat products should be disposed of through regulated markets like other agricultural commodities. Any attempt to increase the productivity of small ruminants, however, must take into account the fact that small ruminants depend heavily upon the responses of the whole agricultural sector to change economic and technological forces and should, therefore, be studied as part of an integrated system.

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INTEGRATION OF CROPS AND SMALL RUMINANTS IN SRI LANKA

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Abstract *Sri Lanka has 517,000 goats and 27,000 sheep with 73.28 and 83.28% of the goats and sheep, respectively, reared in the dry and intermediate zones of the country where climatic conditions are more suitable for small ruminants. Also, sufficient unirrigable lands are available in these agroecological zones because of the lower population density. There is great potential for small ruminant production under plantation agriculture as well as for coconut and rubber.*

These species are reared in Sri Lanka mainly for meat; however, small herds of goats are maintained for milk in the urban areas. The carcass weight of a typical Sri Lankan small ruminant is between 10 and 12 kg; therefore, programs are under way to increase the meat production of local goats by upgrading them with Jamnapari and Boer breeds and the less productive sheep breeds with Dorset, Bannoor, and Red Madras. Goats are also upgraded by crossing with the Sannan breed to improve milk production.

Feed is the next most important constraint affecting small ruminant production. At present, goats are either browsed or grazed, and sheep are mainly grazed under coconut or in established pastures. Periodic droughts, however, reduce herbage production in all these areas. Thus, one of the quickest solutions to the feed problem is integration with crops through efficient use of the available resources as feed such as crop residues and agricultural by-products. Also pasture and fodder produced under tree crops, tree legumes produced on fences and wasteland in farms, and short-duration fodder legumes produced as catch crops during off seasons could be included as additional sources of feed. If the farmer is trained to conserve part of these fodders, the feed problem could also be overcome.

Table 1 gives the livestock population in Sri Lanka for the last decade and compares the production of small ruminants with large ruminants. These statistics reveal that there has been no significant change in the small ruminant population for the past 15 years. This may be because of the low emphasis given to this industry in the country.

The foregoing indicates that major small ruminant production activities are confined to the low country and the dry and intermediate zones. It is important to note that more than 62% of the sheep population is concentrated in one district called Jaffna in the northern peninsula. The major reasons why small ruminant production is confined to the dry, warmer parts of the country may be the following:

- Availability of land because of the lower population density in the dry zone;
- Fair amounts of land available under permanent crops such as coconut in the low country intermediate zone;
- Parasitic problems are fewer because periodic droughts help break the parasitic cycles; and
- The availability of fodder that does not compete with arable land where more economic crops are grown.

TYPES OF SMALL RUMINANTS

Sheep

It is clear from Table 1 that the total sheep population is only 27,000; 17,400 of these are reared in the Jaffna district of the northern peninsula. These northern sheep are mostly of indigenous origin, do not produce wool, and are reared for mutton and manure. At present, these sheep are being upgraded through crossbreeding with the more productive meat breeds of India such as Red Madras and Bannoor.

Few improved breeds have been introduced to the rest of the country. Out of these, the Bekaneri breed, introduced through the government sheep-breeding station in Weeravila in the south; the Dorset and South Down breeds, introduced through the hill country sheep-breeding station in Boralanda; and the

Table 1. Livestock population 1960-1983 (x 10^3).

Year	Cattle	Buffalo	Goats	Sheep
1960	1562	812	491	52
1961	1517	772	492	66
1962	1326	662	454	49
1963	1589	852	538	33
1964	1853	1002	567	37
1965	1904	1501	600	35
1966	1746	772	590	26
1967	1659	765	880	25
1968	1660	783	584	25
1969	1784	765	545	28
1970	1596	736	558	27
1971	1625	737	546	29
1972	1617	748	562	29
1973	1677	714	549	27
1974	1686	736	547	30
1975	1717	818	547	28
1976	1744	854	562	30
1977	1692	797	545	27
1978	1541	814	450	23
1979	1623	844	461	24
1980	1227	843	493	28
1981	1720	898	512	30
1982	1699	879	512	28
1983	1700	910	517	27

Note: Estimates, based on returns by revenue officers.
Source: MRID (1985).

Bannoor and Red Madras breeds, introduced through the sheep-breeding stations in the coconut triangle are being used for the sheep-development activities in the rest of the country. So far, however, little progress has been made (Table 1).

Goats

Goat production in Sri Lanka does hold some potential; however, the contribution of goat and sheep mutton to local consumption is not that significant. Out of the 1.4 kg meat consumed by a Sri Lankan per year, mutton contributes only 0.12 kg/capita per year.

The major portion of this mutton is produced by the common, indigenous goats of unknown origin. The goats are small, variable in colour, and produce a carcass generally weighing 10-12 kg. Unlike the imported goats, they are fairly well resistant to most of the common diseases and pests that prevail in the breeding tracts. According to estimates of the Department of Census and Statistics, 73.28% of the goats and 83.28% of the sheep are found in the dry and intermediate zones, 12.2% of the goats and 2.78% of the sheep are in the low country wet zone, and 14.3% of the goats and 3.85% of the sheep are located in the midcountry and the hill country. They are poor milk producers and are reared mainly for their meat. The average herd size in the dry and intermediate zones is 17.4 and 9.0, respectively (Sowboda 1985).

Very few goats are maintained for milk production, and these goats are kept in the urban areas and in the plantation agricultural areas (tea and rubber plantations) in small herds. The average herd size is five (Sowboda 1985). The breeds maintained for milk production are mainly crosses of Sannan and Jamnapari.

In the past, local goats have been upgraded by crossing with imported breeds such as Jamnapari for meat and milk and Sannan for milk. Recently, a South African meat breed called Boer was introduced to the country by the West German government through a collaborative program with the Government of Sri Lanka. Work done in the past 2.5 years has revealed that crosses between Boer and the rest of the breeds have produced quite promising birth weight and live weight gains (Table 2).

Table 2. Average weight gain and body measurements of goats reared in the Kotukuchchiya government farm.

Breed	Sex	Live weight (kg)							1st year			
		Birth	1st month	2nd month	3rd month	4th month	5th month	6th month	Weight (kg)	Length (cm)	Girth (cm)	Height (cm)
Jamnapari	Male	2.58	6.14	8.58	10.88	12.74	13.06	14.62	22.37	59.4	64.2	66.0
	Female	2.38	3.96	5.70	7.42	8.82	10.62	12.04	18.79	58.0	60.8	60.0
Kotukuchchiya	Male	2.18	6.44	9.46	12.56	14.94	16.30	17.58	27.14	63.6	68.4	70.0
	Female	2.14	5.96	7.90	9.28	10.72	11.99	13.12	18.35	55.4	62.6	62.0
100% Boer	Male	3.60	6.16	9.26	13.84	16.60	19.29	21.84	33.60	61.8	70.8	66.0
	Female	3.36	6.08	9.16	13.38	16.82	19.10	21.46	NA	54.0	57.0	51.0
75% Boer	Male	3.22	7.08	10.38	13.72	16.04	16.84	17.46	NA	NA	NA	NA
	Female	3.00	5.80	7.90	9.70	12.00	12.75	14.33	NA	NA	NA	NA
50% Boer	Male	2.32	4.94	7.36	9.56	11.55	12.68	13.82	23.60	55.0	64.4	63.0
	Female	2.32	5.08	7.94	9.48	11.98	12.80	12.72	20.02	54.6	61.0	58.0

Note: NA, not available.

Source: Department of Animal Production and Health, Ministry of Rural Industrial Development, Colombo, Sri Lanka.

FEED MANAGEMENT SYSTEMS

Small ruminants reared for meat are managed under the extensive management system. Goats are mainly browsed in the shrub jungles, on farmers' own lands, on crown lands, and in the wastelands of the dry zone. Also, goats are grazed on grass produced on coconut and rubber plantations in the intermediate zone and low country wet zone (Table 3). Sheep are mainly grazed under coconut or in established pastures. The details of the stall feeding of goats are given in Table 4. The fodder for stall-fed goats comes from three different sources: cut fodder from scrub jungles, cut tree fodders grown in the farmer's land or outside, and agricultural waste, such as straw and stubble from the farmer's fields. It has been estimated that 1 ha of tree fodders such as *Gliricidia sepium* and *Leucaena leucocephala* could yield up to 6-8 t of dry matter (DM). Also, a similar area of grass under coconut or young rubber could support up to 12 goats or sheep without irrigation.

GOAT PRODUCTION SYSTEMS

Goat production in the dry zone and part of the intermediate zone of the country is mainly confined to monoculture (Table 5). These areas are under food crop agriculture; thus, goat production is confined to unirrigable highlands and scrub jungles. There is very little integration of goats in these areas with other enterprises. Table 3 reveals that farmers depend only to a small extent on crop residues to cover the fodder shortage period during the dry season in the dry and intermediate zones. In the low country wet zone and the intermediate zone, however, goats are mostly grazed and stall fed rather than favouring one or the other means of feeding, because goat production is integrated with other agricultural enterprises such as plantation agriculture: e.g., coconut, rubber, and other food and cash crops. Thus, there is fodder for grazing under the main crops and for stall feeding from fences and cover crops such as *Gliricidia sepium*. The integration of the goat industry, therefore, has taken place to some extent in these agroecological zones.

CONSTRAINTS TO SMALL RUMINANT PRODUCTION

Feed is one of the major problems for small ruminants reared in the dry zone and food crop agricultural areas of the

Table 3. Utilization of different feed resources for goat feeding (%).

District	Grass-land		Scrub jungle		Trees and bushes		Crop residues		Tank banks		Crown land		Road-side	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mannar	18	15	40	33	22	10	3	23	3	7	11	8	3	4
Jaffna-Mulative	25	27	23	22	16	10	12	17	7	7	11	11	6	6
Anuradapura-Polonnaruwa	20	20	30	27	20	13	8	24	8	5	7	6	7	5
Chilaw	11	17	39	43	30	21	-[a]	4	-	-	14	9	6	6
Kurunagala	52	68	12	8	21	12	3	-	-	2	-	4	12	6
Gampalia	66	62	-	-	14	11	3	3	-	-	3	8	14	16
Mean	32	35	24	22	20	13	5	12	3	5	8	8	8	7

Source: Sri Lankan - German Goat Development Project.

[a] Dashes indicate that feeding practices are not used during the specific period.

Table 4. Stall feeding of goats (%).

District	Cut grass		Cut legumes		Cut bushes		Cut tree fodders		Agricultural waste		Own by-product		By-products purchased		Concen-trates purchased	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mannar	20	8	-[a]	-	33	35	9	13	23	23	-	3	8	9	7	9
Jaffna-Mulative	20	19	5	5	16	16	24	23	15	15	3	4	6	6	11	12
Anuradapura-Polonnaruwa	6	7	14	12	29	26	29	30	15	18	1	4	-	-	6	5
Chilaw	23	-	-	-	9	-	62	80	-	-	-	-	-	-	5	2
Kurunagala	13	10	3	6	4	-	50	62	9	10	2	2	1	2	18	18
Gampalla	3	-	-	-	2	3	83	86	-	-	-	-	-	-	83	11
Mean	14	7	4	4	16	13	43	47	10	11	1	2	3	3	10	12

Source: Sri Lankan - German Goat Development Project.

[a] Dashes indicate that feeding practices are not used during the specific period.

Table 5. Feeding management of goats (%).

District	Wet season			Dry season		
	Grazing only	Grazing and stall feeding	Stall feeding only	Grazing only	Grazing and stall feeding	Stall feeding only
Mannar	56	32	12	59	36	5
Jaffna-Mulative	25	46	29	31	46	23
Anuradapura-Polonnaruwa	47	34	19	57	33	10
Chilaw	54	31	15	62	38	0
Kurunagala	20	44	36	31	46	23
Gampalia	17	56	27	44	47	7
Mean	36	41	23	48	41	11

Source: Sri Lankan - German Goat Development Project.

intermediate zone. Because of the fairly large herd sizes maintained in these areas, periodic fodder shortages occur during the dry months of the year (June-October). Farmers underfeed the goats during this period, and it is only at this time of year that they depend on agricultural residues to compensate for the green herbage shortage.

Also, in some of the new agricultural development areas, livestock farmers face shortages of land because of the expansion of crop production. The small ruminants are excluded from these areas because they damage the growing crops. This situation has caused the producers of small ruminants to change to new systems of management and new sources of feed to suit the management system.

There is no feed problem in the low country wet zone and plantation areas of the intermediate zone as long as the herd is kept small; however, the economics of keeping such units primarily for meat production under semi-intensive management is questionable.

The following are among some of the other problems affecting the effort to increase productivity:

- Indigenous goats and sheep are small (about 22 kg) when compared with breeds such as Jamnapari and Dorset, which reach a mature weight of about 35 kg;
- Milk production is very low; some does and ewes do not even have sufficient milk to feed their kids;
- Most of the farmers do not have an organized feed or fodder production program; thus, the animals do not get a steady, year-round supply of feed;
- Small ruminant production is a side business among most of the farmers and is, therefore, given less attention by the farmer;
- Diseases and parasites in some areas and predators in others cause constant problems for the farmer;
- In the past, small ruminant production has been given a low priority by the government;
- Lack of management skills among the farmers; and

- Shortage of improved breeding material.

Among the innovative changes that are essential to improving the small ruminant industry are the following:

- Farmers should be encouraged to produce high-quality herbage in fences and as intercrops with permanent crops. In Sri Lanka, tree fodders are recommended.

- Lands under permanent crops, such as coconut, young rubber, and fruits, could be intercropped with grasses and creeping legumes.

- It was reported that 65-70% of the crop bulk produced by the farmer has no market value. These crop residues could be conserved and fed to small ruminants during the fodder shortage. Sri Lanka produces about 5 x 10^6 t of agricultural residue annually, about 3.2 x 10^6 t of which is rice straw (Rajaguru 1985a,b).

- Farmers could be encouraged to produce short-duration leguminous crops like greengram and other pulses for fodder in the rice fields in between the cultivation seasons by taking advantage of the residual moisture. These fodders could be conserved or directly used for feeding small ruminants.

- Sri Lanka produces about 0.8 x 10^6 ha of paddy, and if the paddy bunds in the areas where small ruminants are raised are planted with legumes such as Stylosanthes or any other suitable bush legumes, part of the fodder requirement for livestock could be achieved.

- If the excess fodder produced during the lush season is conserved in the form of hay or silage, added herbage sources will also be available.

- Sri Lanka produces large quantities of agricultural by-products such as rice by-products, coconut and rubber seed oil meal, etc. (Rajaguru 1985a,b). If these by-products are incorporated with the herbages discussed earlier, a sedentary well-fed small ruminant industry could develop.

It is clear from the foregoing explanation that the small ruminant industry could be made more economical under less expensive, intensive browsing management. The present herd management practices will not permit any adoption of improved techniques. Thus, the management systems must be integrated with other agricultural enterprises for their mutual benefit to obtain maximum results from the small ruminant industry. If such a system is implemented, Sri Lanka has the potential to produce part of the much-needed milk and most of the meat requirements of the country from small ruminants.

RECOMMENDATIONS

Sri Lanka has about 0.5×10^6 ha of coconut, and more than 50% of this land is situated in the intermediate zone. If 40% of this land could be brought under sheep production at a stocking rate of 12 sheep/ha, there could be a sheep population of more than 1.2×10^6 in the intermediate zone. This value is twice the present small ruminant population of Sri Lanka. Sheep are recommended here only for mutton under extensive management in coconut plantations.

Goats, however, could play a dual role in providing meat, milk, or both. Although meat goats are strongly recommended, especially for more arid areas of the eastern, northwestern, and southeastern areas, the rest of the country is more suited to producing milk or dual-purpose goats because the indigenous cattle are also very poor milk producers. The daily milk production of an indigenous cow is about 1 L. Thus, a milk goat could easily replace a cow with one-fifth of the feed and care needed by a cow.

This type of goat becomes more important under the present farming setup where 1 ha is the average agricultural holding size. It will be more convenient, therefore, for the farmer to have a productive doe than an unproductive cow because of the limited feed resources available. Also, a herd-improvement program toward a dual-purpose animal will help to achieve higher body weight gains and production standards in large herds reared even for mutton production.

Such an achievement will provide much-needed milk to the rural homes, and the excess stock could be sold for mutton. Thus, the goat production that is confined to non- or semi-agricultural areas could be easily integrated with agriculture.

To achieve the foregoing objectives, the following suggestions are made:

- Formulation of a well-planned policy for small ruminant production by the government and identification of areas to be demarcated and efforts to be concentrated in each area to achieve the objectives quickly;

- Improved breeding animals and artificial insemination facilities should be organized on a regional basis by establishing public as well as private breeding farms;

- Organized training programs should be implemented to train farmers on improved techniques of small ruminant production;

- Farmers should be trained in the production, conservation, and utilization of herbage and enrichment of agricultural residues;

- Producer associations and cooperatives should be set up to safeguard the interest of the producers in marketing of produce and procurement of inputs; and

- Affordable loans and subsidies should be made available for the producers most in need.

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INTEGRATED CROP AND SMALL RUMINANT SYSTEMS IN BANGLADESH

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Abstract *This paper discusses the importance of small ruminants in the agricultural economy of Bangladesh. Goats are considered to be an integral component of farming systems in Bangladesh. This animal has been one of the country's major sources of foreign exchange and goat-processing industries are an important source of employment. Feeds, fodder, and diseases are considered to be major constraints to goat and sheep production. As the vast majority of goats and sheep are raised by small farmers, especially women and children, who own little or no land, it is essentially impossible for them to stimulate improved production by growing feeds and fodder for their animals. Selection of high-yielding fodder, forages that are suitable for relay or intercropping, and planting with woody legume trees on wasteland might increase the availability of green roughage. It is essential that research on small ruminants be carried out in a farming-system context under village conditions, where the stresses experienced by these animals are often different from those experienced on the experimental station.*

Bangladesh consists largely of a delta with a riverine environment and experiences floods in one-third of the total land area each year. The average temperature in the summer is 35°C; in winter, it is 11°C. The annual rainfall (monsoon) is 117-340 cm. Bangladesh has a population of about 94 million, with a density of 620 people/km^2, which is considered among the highest in the world. About 84% of the people live in rural areas.

Agriculture plays a major role in the economy and accounts for about 50% of the gross domestic product (GDP), 67% of employment, and more than 80% of export earnings. Livestock in Bangladesh is an essential component of crop farming, supplying the major part of the draft power required for land cultivation and transport. In addition, they supply meat, milk, and eggs for human consumption; hides and skins; and bones and horns as raw materials for industry and export. Animal manure is an important source of fertilizer for crops and for fuel for domestic use.

The livestock sector contributes about 4.9% of the total GDP. Virtually all the animals are kept on small farms, and livestock farming is a secondary and supportive activity to crop farming. The farmers are involved in crop production, raising crops with a pair of bullocks for use as draft power for the farmers' cultivation needs and partly to hire them out to neighbours. There may also be one or two cows, goats, or sheep for milk and eventually for meat. A few chickens and ducks are kept for their meat and eggs and are usually cared for by the housewives. The number of animals per rural household averages 2.6 cattle or buffalo, 1 goat or sheep, and 7.5 poultry. The average stocking density of cattle and buffalo is about $177/km^2$ (ADB 1984).

With the increasing human population (2.4% per year), farm size decreases and farms are further fragmented from generation to generation. The usual size of the landholding is extremely small, the average being about 2 acres (0.8 ha) with about 50% being less than 1 acre (0.4 ha) (Table 1).

The livestock population of Bangladesh is estimated at about 22×10^6 cattle, 0.5×10^6 buffalo, 10.5×10^6 goats, 0.5×10^6 sheep, and 90×10^6 poultry (ADB 1984). Annually, they provide 2.3×10^6 hp (1 hp = 746 W) of draft, 0.29×10^6 t of meat, 1×10^6 t of milk, and 4.5×10^6 pieces of hides and skins (World Bank 1982).

LAND UTILIZATION AND ANIMAL FEED RESOURCES

In an intensive agrarian country like Bangladesh, feed resources for ruminants are mainly derived from crop residue by-products from food grown for human consumption, as well as from grasses and legumes that can be grazed on fallow land, river embankments, roadsides, bunds, and between fields. Aquatic plants and tree leaves are also eaten.

Table 1. Size and distribution of agricultural holdings in Bangladesh.

Size (acres)	No. of households (x 10^3)	% of total
0	1979	12.32
0.01-1.0	5802	40.11
1.01-2.5	2660	21.70
2.50-5.0	1436	13.86
5.01-7.5	501	5.57
7.50-10.0	205	2.43
>10	283	3.94

Note: 1 acre = 0.404 ha.
Source: BBS (1985).

A total of 77% of all the cultivable land is being used for production of rice; 10% is in ponds, depressions, rivers, and canals; 3% each for oilseeds and pulses; and 1% each for sugarcane and others (Jackson 1980). Rice straw is by far the most important crop residue, contributing more than 90% of the total feed available to the ruminants, especially cattle and buffalo. A livestock feed inventory giving the quantity of feedstuff available for ruminants in Bangladesh is shown in Table 2. About 2 kg of straw dry matter (DM) and 80 g of concentrate are available per head per day. Under these conditions, administering a conventional balanced ration is difficult because of the lack of available feedstuffs, both quantitatively and qualitatively. The alternative is to import feedstuffs, especially concentrates, which is obviously undesirable. The strategy, therefore, is to properly manage the limited amount of available feed supplements (cereal and animal by-products, green grasses, tree leaves, etc.) to ensure the most efficient, optimum utilization of basic feeds such as

Table 2. The availability of livestock feed in Bangladesh.

Feedstuff	Quantity (x 10^3 t DM)	Daily availability (kg/head)
Straw		
Rice straw	14955	
Wheat straw	264	
Total	15219	2.01
Grasses	1219	0.20
Concentrates		
Oilcake	168	0.02
Brans	697	0.06
Sugarcane tops	192	0.03
Fodder and forages	81	0.01
Molasses	10	0.001

Source: World Bank (1982).

crop residues, green roughages, and the small quantity of available concentrates.

SMALL RUMINANTS IN THE NATIONAL ECONOMY

Goats and sheep make up about 31 and 1.5%, respectively, of the total livestock population in the country. They are multipurpose animals producing meat, milk, skins, hair, and wool. Estimated production of meat and milk from livestock from 1977 to 1981 is shown in Table 3. Goats produced more than 20% of the total meat and 28% of the total milk production from livestock. The contribution of goats and sheep in comparison to cattle and buffalo in supplying meat and milk is shown in Figs. 1 and 2. The relative contribution of buffalo in meat and milk production is about 1.6 and 2%, respectively, of the total production. Figures 1 and 2 also show that milk production by cattle and buffalo has decreased by 10% from 1977

Table 3. Estimated meat and milk production from 1977 to 1982 and projected estimation from 1985 to 1990.

Products	1977	1978	1979	1980	1981	1985	1990
Meat (x 10^3 t)							
Cattle	202.2	196.8	199.4	201.3	204.9	206.0	231.9
Buffalo	8.4	4.7	4.7	4.7	4.7	4.7	5.3
Goat	41.9	45.6	49.6	54.0	62.8	76.9	118.6
Sheep	1.2	1.4	1.9	2.3	2.7	3.4	5.2
Poultry	19.2	19.9	20.5	21.1	22.4	24.5	32.6
Annual per capita consumption (kg)	3.3	3.2	3.2	3.3	3.3	3.2	3.6
Milk (x 10^3 t)							
Cow	686.9	668.4	677.3	683.7	696.4	699.6	766.8
Buffalo	28.6	15.9	15.9	15.9	15.9	15.9	17.4
Goat	183.2	199.4	216.9	235.9	274.8	336.5	472.0
Sheep	2.5	3.2	3.8	4.6	5.5	6.8	9.6
Annual per capita consumption (kg)	11.0	10.6	10.7	10.8	10.8	10.7	11.6

Source: ADB (1984) and BBS (1985).

to 1981, whereas goat milk production has gone up by 57% during the same period. It also appears that cattle meat production decreased by 9%, whereas it has gone up by 37% in goats. This increased milk production relates to an increased goat and sheep population.

The export of hides and skins has been the country's third major source of foreign exchange earnings over the last 5 years and their processing industries are an important source of employment. These earnings have been fairly substantial over the last decade, although they declined somewhat from 1980 to 1982 because of a slump in world market prices (Fig. 3).

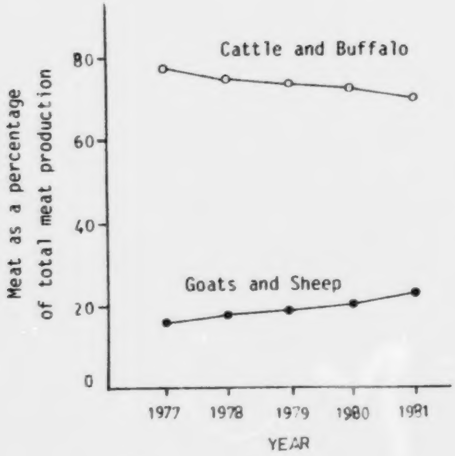

Fig. 1. Contribution of large and small ruminants to total meat production in Bangladesh (ADB 1984, adapted).

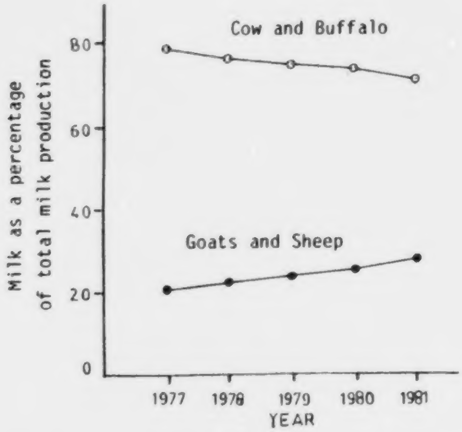

Fig. 2. Contribution of large and small ruminants to total milk production in Bangladesh (ADB 1984, adapted).

Figure 3 shows that the production of goat skins has increased from 1977 to 1982. In 1981-82, buffalo hides and sheep skins represented 3.4 and 4.3%, respectively, of the total production of hides and of skins. Wool production from sheep has increased from 40 t in 1978-79 to 53 t in 1982-83 (BBS 1985).

BREEDS AND MANAGEMENT OF GOATS AND SHEEP

There are two main varieties of indigenous goats in Bangladesh: the Black Bengal, which makes up the majority of the country's goat population, and the somewhat larger White Bengal. There are a good number of pure Jamnapari, and its crosses with local goats are also found in certain areas of Bangladesh. Most probably, these goats were introduced into Bangladesh from India in 1947. The Black Bengal is well adapted and is one of the most productive goats under local conditions. Their legs are short and their body is deep and small. Bucks weigh 14-16 kg; nannies, 9-14 kg. The coat is short, lustrous, and hairy. The body colour is black or black with brown or white marks. There are a few goats with brown or white marks, or brown or white coats. Both sexes have small to medium (6-12 cm) length horns, the ears are short (11-14 cm), and beards are common on either sex. The birth weight of kids ranges from 0.4 to 0.8 kg, depending on the number of kids born. The weaning weight of kids is from 6 to 8 kg with an average weaning age of 131 days. Nannies kid twice a year and twins or triplets are common (more than 50%).

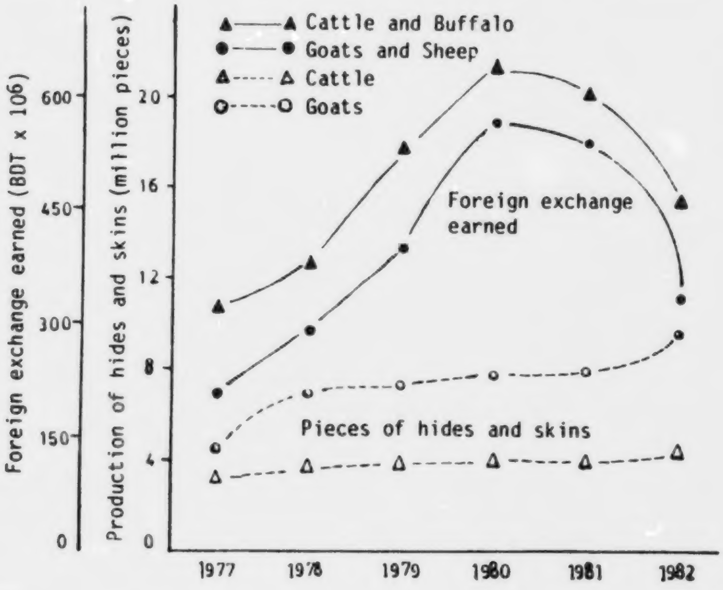

Fig. 3. Production and foreign exchange earning (in 1986, 33 Bangladesh taka (BDT) = 1 United States dollar (USD)) from hides and skins from 1977 to 1982 (BBS 1985, adapted).

Sheep in Bangladesh are indigenous, small, varied in colour, have hairy wool, and show poor prolificacy. They are kept mainly in large flocks in the southern and northern part of the country. The mature weight is as low as 10 kg for ewes and 15 kg for rams. Although they are kept primarily for meat production, they also annually produce about 500 g coarse wool per sheep.

Although different management systems exist in the developing countries for raising sheep and goats, the village system is the only system practiced in Bangladesh. The vast majority of goat production is maintained by poverty-stricken farmers, especially women and children. There is no maintenance cost in this sedentary system of grazing on harvested fallow land, on road and canal sides, and overgrazed commons, where the goats are generally tied to a short rope. Very little or no concentrates are provided except from household scraps or their by-products. Most often, the goats are housed in a small thatched shed or in a room attached to the cattle shed. External and internal parasitic infestation are the common disease problems in goat raising.

INTEGRATION WITH CROPPING SYSTEMS

The estimated and projected livestock population from 1977 to 1990 is shown in Table 4. Based on this estimate, it was observed by ADB (1984) that the annual cattle and buffalo population growth rate was less than 1%. This is probably because of the increasing farm fragmentation and decreasing feed and fodder availability. The annual goat, sheep, and poultry population growth rate, however, is closer to that of the human population (2.4% per year). As the human population increases and the pressure on land becomes greater, the need for small, highly efficient livestock increases, as does the total contribution of small ruminants to the national economy. Increased production efficiency can be expected from goats because they have higher reproductive efficiency with the potential for increased litter size, shorter gestation intervals, and relatively higher fertility. For these reasons, small-scale farmers are more inclined to raise goats when feed is the major constraint caused by the scarcity of land. A survey report by Lassen and Dolberg (1985) in the Noakhali district reflected a similar situation (Table 5). They reported a 32% increase in the goat population from 1979 to 1984 in the project area. They concluded that the landless and nearly landless farmers are keeping more goats. The households

Table 4. Estimated livestock population (x 10^6) from 1977 to 1982 and projected estimation from 1985 to 1990.

	Estimated						Projected	
Species	1977	1978	1979	1980	1981	1982	1985	1990
Cattle	21.6	21.0	21.3	21.5	21.9	21.9	22.0	22.0
Buffalo	0.9	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Goat	6.8	7.4	8.1	8.8	10.2	10.2	12.5	17.5
Sheep	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.8

Source: ADB (1984).

with more than 2 acres (0.8 ha) of land have reduced the number of goats.

A more recent survey by the Bangladesh Agricultural University Farming Systems Research and Development Programme (FSRDP 1986) has shown a similar trend in goat raising by smallholder farmers in a village of the Mymensingh district. In that village, 28 farming production systems were identified among the 200 households, of which 87% of the households have livestock as a component of farming systems. In other words, 23 production systems have livestock as a farming component. It has also been observed that goat raising is a farming component in 14 of 23 production systems that include livestock as an enterprise. The percentage of different types of livestock in relation to the size of the landholding is shown in Fig. 4. Landless to marginal farmers (0-0.5 ha) keep the highest percentage of goats.

The relationship between land and types of livestock holding in the Kazir Shimla village of the Mymensingh district is shown in Table 6. It appears that the highest number (66) of goats are kept by farmers holding 0-0.5 ha of land, which accounts for 44% of the total goat population. This group (39% of total households) also keeps 33% of the cows and 5.8% of all

Table 5. Relationship between land and livestock holdings in a village of the Noakhali district.

Landholding (acres)	Households		Bullocks		Cows		Young stocks		Goats	
	1979	1984	1979	1984	1979	1984	1979	1984	1979	1984
0	159	137	17	0	13	10	14	15	37	64
0-0.5	39	48	10	4	20	28	11	11	16	40
0.5-1.0	31	52	24	25	9	43	11	12	16	22
1.0-2.0	44	46	51	57	31	49	18	25	39	47
2.0-3.0	26	16	39	25	10	16	25	17	29	12
>3	18	18	30	33	13	20	17	11	9	7
Total	317	317	171	144	96	166	96	91	146	192

Note: 1 acre = 0.404 ha.
Source: Lassen and Dolberg (1985).

bullocks (Fig. 4). A higher number of bullocks (33%), however, is kept by households having more than 2 ha of land.

INCREASING THE LEVEL OF PRODUCTION

To increase the level of production, it is important to identify the problems related to lower productivity of small ruminants, namely feeds and fodder, care and management, breeding, and disease.

Feeds and Fodder

A major constraint to small ruminant production is the severe scarcity of feed. Various opportunities for improving the feed supply and quality exists in this country. One method is to increase crop residue production by increasing the cropping intensity and utilizing nonconventional agroindustrial

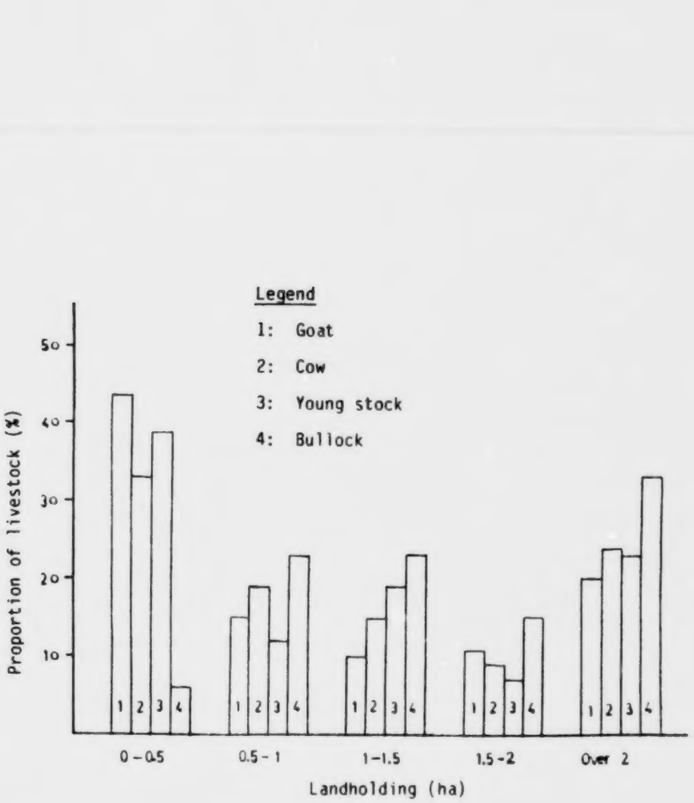

Fig. 4. Relationship between landholding and different types of livestock in Kazir Shimla village of Mymensingh (FSRDP 1986, adapted).

by-products. Although the area under rice cultivation has increased in Bangladesh, the net availability of rice straw has decreased (Jackson 1980). Among the reasons for this is a large increase in acreage in the boro season and this type of rice is harvested in monsoon. Because of the difficult drying situation, most of the straws rot and become unsuitable for animal consumption. Apart from the nutritional benefits of treating straw with urea or lime, it is important to note that these chemicals can also be used to preserve wet straw (Dolberg et al. 1982) and, thus, increase the availability of straw for livestock feeding. In addition, it seems to be extremely cost effective to use urea or lime to treat straw, e.g., to save 1 kg of straw (equivalent to BDT 1.0), only 50 g of urea is required (equivalent to BDT 0.25) (in 1986, 33 Bangladesh taka (BDT) = 1 United States dollar (USD)). Moreover, the nutritive value of the treated straw also increases significantly.

In terms of selecting high-yielding grain and straw varieties, the local varieties of rice are being replaced by the dwarf and intermediate high-yielding varieties, which yield less straw per unit of land than the local type of rice; as such, there is a possibility that total production of straw might be reduced (Jackson 1980). It has also been reported by

Table 6. Relationship between land and livestock holdings in a village of the Mymensingh district.

Landholding (ha)	% of total households[a]	Goats	Cows	Bullocks	Young stocks
0-0.5	39	66 (44)	52 (33)	4 (6)	39 (39)
0.5-1.0	16	22 (15)	30 (19)	16 (23)	12 (12)
1.0-1.5	15	14 (10)	24 (15)	16 (23)	19 (19)
1.5-2.0	5	17 (11)	14 (9)	10 (15)	7 (7)
>2	12	30 (20)	37 (24)	23 (33)	23 (23)

Note: Values in parentheses are percentages of each type of livestock.

Source: FSRDP (1986).

[a] Households with no livestock made up 13%.

the farmers in Bangladesh that straw from high-yielding varieties of rice is less acceptable than the local varieties. Haque et al. (1981) observed a significant difference in dacron bag DM digestibility of straw between the local variety of Naizershail and the high-yielding varieties of BR-3 and BR-4; however, the straw from IR-20 and BR-5 was found to be as good as the straw from Naizershail with respect to DM digestibility. They could also increase the DM digestibility of different varieties with lime.

Saadullah (1983) reported that there was no significant difference among the different local and high-yielding varieties (two local and five high yielding) with respect to cell contents, cell materials, hemicellulose, lignin, crude protein, and ash contents. Swapan and Saadullah (1985) compared the natural variability in chemical composition and nylon bag digestibility of straw from the rice varieties of Paijam, Patnai, Dhulabog, BR-4, BR-10, DA-31, DA-29, B-I, B-II, and B-III. The highest and lowest DM digestibility of 70 and 44% were observed with the varieties of Patnai and BR-4, respectively. Such variation in digestibility of straw might also exist for other local and high-yielding varieties of rice. There is a need for a systematic study to assess the quantity and quality in terms of nutritive value as cattle feed, which is directly related to more intake and productivity. It is felt that identification of superior varieties can influence plant-breeding research, initiating breeding to increase the quality of straw and encourage high grain yield.

Although straw is relatively abundant, there is not enough to meet the needs of all the cattle and buffalo. It should be noted that straw is also used for fuel and construction of thatched houses. A village study in Bangladesh shows that as much as 45% of the fuel used for cooking comes from straw (Briscoe 1979). In this context, livestock feeding relates to other aspects of biogas production, such as tree planting, as both activities could increase the amount of straw for livestock feeding.

In terms of agroindustrial by-products, the use of nonprotein nitrogen, such a urea, can be of considerable importance because of the high cost and unavailability of concentrates. Molasses has been used as a supplementary energy source for microbes in the rumen for efficient utilization of nonprotein nitrogen and optimum digestion of straw and microbial protein synthesis. Saadullah (1978) observed a decrease in organic matter digestibility of straw beyond 10-15% molasses with 2% urea nitrogen in the mixtures. Urea molasses block licks were found to be very effective with straw-based diets in increasing the daily live weight gain and milk production in cattle and goats (Kunju 1986; M. Saadullah and S.C. Das, unpublished). Sugarcane tops and bagasse could also be another means of increasing the availability of crop residues.

To increase the availability of green roughages, supplementation of fodder, forages, and water plants is recommended. Supplementation of small quantities of green roughages with straw-based diets in ruminants appears to have a beneficial effect on rumen fermentation. Nolan and Staciew (1979) observed that it was difficult to maintain sheep on chopped straw unless 50 g of lucerne was included in the ration. Perdok et al. (1982) found that daily supplementation of Gliricidia (6 kg/cow) with urea-treated and untreated rice straw increased live weight gain as well as milk production. Aquatic plants such as water hyacinth and azolla can also be a good source of green roughages to supply protein in the ruminants' diet. Azolla supplementation to the lower quality roughages stimulated better performance in crossbred heifers (Singh 1980).

Using Shahiwal local calves, Hamid et al. (1983) observed significant increases (295 g/day compared with 222 g/day) in live weight gain when they gave a daily supplement of 200 g water hyacinth on a DM basis to a basal diet of urea-treated straw with 150 g of fish meal compared with roadside grasses. Wanapat (1983) has also reported a definite improvement in animal productivity by supplementing water hyacinths in the diets of urea-treated straw. Saadullah (1984; Saadullah et al. 1985) evaluated the quality of different leguminous and aquatic plants in terms of degradability of protein in the rumen. He observed that the protein from ipil ipil leaves, Sesbania aculeata, and water hyacinth was a good source of undegradable protein, superior even to that of oilcakes and soybean meal.

Because green fodder is difficult to find, water hyacinths could meet part of the requirement of green roughages. One way of increasing fodder production for livestock would be to produce maximum DM using the minimum amount of land (Table 3). This could be achieved through improved farming systems using intercropping, relay cropping, or mixed cropping. Cereal-legume intercrops have proven in many cases to provide the greatest production per unit time and per unit land, and to reduce the nitrogen requirement for the next crop (Khan 1981). There is considerable potential for growing legumes in the dry season, particularly after aman rice is harvested as an intercrop or relay crop. Investigation into the range of available legumes and testing them under local conditions is required. Plantation of legume trees like ipil ipil around homesteads and embankments and planting Sesbania and pigeon pea in hedges along roadsides and bunds could also be a way of increasing the availability of green roughages. Weeds are also being used by the farmers as an important source of green roughages in Bangladesh. The quantity and quality of these weeds, however, are not known.

Another means of improving feed and fodder is to improve the nutritive value and utilization by physical, chemical, and biological methods. Rice straw, for example, has a low feeding value because of its inherent low digestibility, low nitrogen content, and imbalanced mineral composition and, coupled with low intake, this straw is not enough to maintain an animal. Chopping and water soaking of the straw before feeding cattle has been practiced by farmers for a long time. Saadullah and Haque (1981), however, observed that neither chopping nor water soaking could improve the digestibility, although there was an increase in intake. Chemical treatment of straw was found to be one of the most effective methods of increasing digestibility and protein content (ammonia treatment).

Considering the facts, there is a growing interest in increasing the feed value of straw through chemical treatments. Jackson (1978) has reviewed the known methods of straw treatment. In relation to Bangladesh, however, they had limitations. Caustic soda is expensive and dangerous to handle, and the technique used in developed countries is very difficult to follow by farmers in the villages. Anhydrous ammonia, for example, requires airtight covers and sophisticated equipment to carry in to the villages. In this context, urea as a source of ammonia was used in treating straw using indigenous materials for the treatment processes (Dolberg et al. 1981; M. Saadullah and S.C. Das, unpublished). Under temperatures of 20-25°C (an elevated temperature in the stack during treatment), treatment is completed after 6 or 7 days. Fertilizer-grade urea was added with water (water-straw, 1:1) at the rate of 5% air-dry straw and sprayed over the straw. The following methods were developed in Bangladesh: bamboo basket, hessian sack, earthern pit or brick pit, and the stack method. The farmer's choice of method depends upon the quantity of straw to be treated, the time, and the farmer's financial condition. The comparison between the effect of feeding urea-treated and untreated straw with or without supplementation of concentrates on the performance and efficiency of feed utilization in calves is shown in Fig. 5.

Management, Breeding, and Disease

The productivity of small ruminants depends on proper management inputs. Faulty housing management and caring for kids, especially weaning and pregnant does and ewes, represent major economic losses to the farmers in Bangladesh. The simple extension of technical advice will not ensure successful development without acknowledging the importance of management inputs. Management variables like housing, breeding practices, selective feeding, and feed treatments that produce a positive impact on production and reproduction performance should be intensified.

Genetic selection for increased production among local genotypes under existing or improved management systems could be useful for any wide-ranging program to improve small ruminant production, especially goat production. The selection program should include the level of fertility, prolificacy, growth rate, and the quality of skin. Considerable opportunities exist to select particular traits among local breeds and to assess their potential in the environment to which they are adapted.

Illness is a major problem among village goats. There are a number of goat and sheep diseases that lower productivity; however, there is little information on the relative importance of those diseases on small ruminant productivity. Undoubtedly, parasitic control is needed to increase the productivity of goats. Parasitism is mainly caused by ecto- and endoparasites, which are associated with poor nutrition and reduced disease resistance.

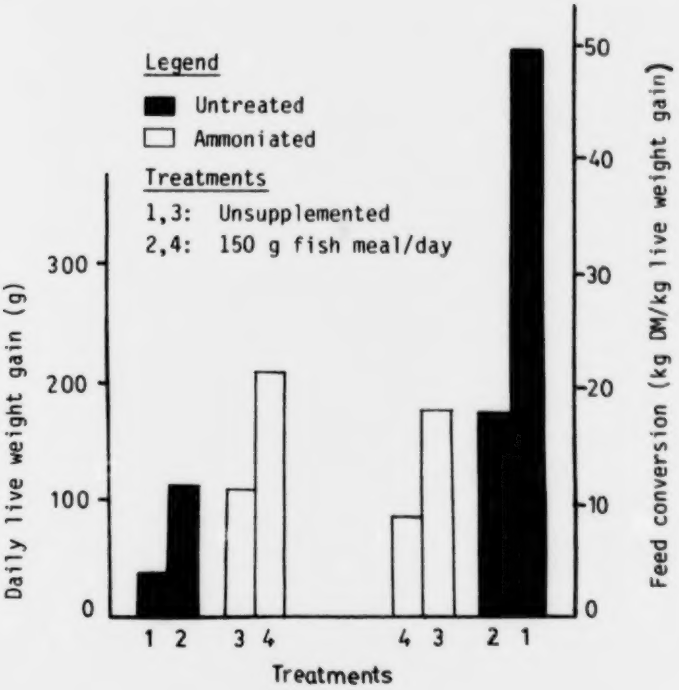

Fig. 5. Effect of supplementing rice straw with fish meal on live weight gain and feed conversion.

CONCLUSIONS

Goats are an integral component of the farming system in Bangladesh. There is significant potential for increased goat meat and milk production. As such, the research priorities should be directed toward

- Identification of present productivity and management constraints at the village level;
- Nutritional requirements of goats;
- Developing appropriate technologies to strengthen the linkages between land, crops, and goats under the small-scale farm environment;
- Integration of goat raising with crop and marginal land, which will involve both production and economic aspects;
- Selection of goats for increased production among the local genotypes, which should include the prolificacy, fertility, growth rate, and the quality of skins; and
- Investigation of the relative importance of different goat diseases and their effect on productivity, especially ecto- and endoparasites.

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INTEGRATION OF SMALL RUMINANTS AND MIXED DECIDUOUS FOREST IN NORTHERN THAILAND

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Abstract *A flock of 41 goats were grazed and browsed on an area of about 80 ha, which is 70% mixed deciduous forest and 30% abandoned swidden. The main forest tree species and undergrowth within the forest were identified. Dry matter yields of grasses, climbing plants, and shrubs in the forest and abandoned swidden was about 2400 kg and had 8.33% crude protein content on a dry matter basis. Productivity of the flock was compared with another flock in a Chiang Mai suburb.*

Another case study was done with 25 sheep under a 24-ha teak plantation and about 2 ha of cultivation area. The main undergrowth within the teak plantation was identified. The sheep live weight at different ages was compared with the other flock. There was no apparent difference in the performance among these flocks.

The careful manipulation of the stocking rate with available dry matter production is an important consideration for the success of the integration system. Goats should be able to adapt better to the system than sheep.

The northern region of Thailand covers an area of approximately 169,644 km^2 or about one-third of the total area of Thailand. It is estimated that northern Thailand has about 87,756 km^2 of forest area or about 56% of total forest area of the country. Because of this, the agroforestry system is very important for animal production in this region. The utilization of the forest as grazing and browsing areas for cattle and buffalo has long been recognized in many villages, whereas for goats and sheep, the system is not well established. This paper presents the integration of small ruminants and mixed deciduous forests in northern Thailand from two case studies and a discussion of the potential trend of the system for promoting sheep and goat production for the region.

POPULATION AND THE IMPORTANCE OF SMALL RUMINANTS

At present, there are about 73,644 goats and 44,877 sheep in Thailand (Table 1). The number of goats and sheep in Thailand is small compared with the number of other ruminants, but they do seem to have increased steadily over the last decade (Table 1). Because of the rapid growth of the human population, the demand for goat and sheep products, both for domestic consumption and for export, has also increased. Goat products, such as meat, milk, and skins, are consumed more readily than sheep products. Unfortunately, there are no consumption statistics available.

According to the local traders, the demand for goat and sheep meat increases during the cool, dry season (September to February). It was roughly estimated that 2000 goats are brought from Burma to Thailand during this period to be sold monthly for meat consumption. Goat milk is sold mostly in the city in small quantities. Sheep product consumption can be also roughly estimated from the import statistics of the Department of Livestock Development (Table 2).

Because there are many sheep slaughtered in the country, the home consumption of mutton and lamb is at least 41,806 kg/year. The potential exists to increase sheep production in Thailand. The Baptist Mission has introduced the utilization of sheep for the purpose of making blankets and jackets both for home use and to sell as handicrafts among Karen hill-tribe villages. Housewives can earn extra income by spinning and weaving during their free time. This program has attracted the interest of the Public Welfare Department, which will promote this aspect of sheep production in its rural development program. This means that sheep production can benefit small communities. The role of sheep and goat production in rural development is of great benefit to the communities and should not be overlooked.

FOREST TYPES IN NORTHERN THAILAND

In Northern Thailand, there are two main forest types covering the total land area: evergreen forests and deciduous

Table 1. Number of goats, sheep, cattle, and buffalo in Thailand, 1975-1984.

Year	Goats	Sheep	Cattle	Buffalo
1975	48230	71357	4141725	5596876
1976	53519	33340	4322375	5895418
1977	57136	19652	4341152	5827462
1978	63138	18551	4436607	5958734
1979	66503	31755	4275825	6027895
1980	55539	21766	3938221	5650794
1981	37561	21357	4468796	6124091
1982	48883	27081	4578699	6417433
1983	58520	32785	4832570	6354349
1984	73644	44877	4788989	6300896

Source: Office of Agricultural Economics (1985).

Table 2. Imported sheep products, 1981.

Item	Amount (kg)	Country
Sheep intestine	6044	Australia, New Zealand, and the Federal Republic of Germany
Mutton, lamb	41806	New Zealand, France, and the Netherlands
Skin	353	Australia
Stomach	68	England
Ribs	120	New Zealand
Wool	191679	New Zealand

Source: Adapted from the Department of Livestock Development (1981).

forests. These forests, of course, vary according to the local environment, i.e., soil types, soil moisture, atmospheric humidity, season, annual rainfall, temperature, and elevation.

Kijkar (1985) classified the forests of northern Thailand with particular emphasis on the Chiang Mai basin; the results of this study can be summarized as follows. The dry, dipterocarp forests occur mainly on the foothills or the flat lands where soils are very poor and generally at elevations less than 1000 m. Forest trees are generally gnarled and stunted on the shallow podsolic or lateritic soils. Mixed deciduous forests are the most important source of economic timber in the country because of the presence of teak and many other species of economic value. Mixed deciduous forests are located on better soils than are the dry dipterocarp forests. Dry evergreen forests can be found both on the lowlands and on the uplands at less than 1000 m elevation where soil is moderately fertile, has a high content of soil moisture, and has clay or sandy clay loams. Hill evergreen forests are located at altitudes above 1000 m on fertile clay loam. At this high altitude, the average annual rainfall is considerable. Pine forests occur within limited areas on the ridges or on the hill slopes at elevations greater than 700 m where soil is either shallow or infertile because of very high acidity or dry sandy soil.

The northern region of Thailand has more forest area than any other region: 87,756 km^2 or about 56% of the total forest area of the country (Table 3). The forest of the north consists of 29.74, 28.49, and 39.11% evergreen, mixed deciduous, and dipterocarp forest, respectively. With the increase in population pressure, the need for more land for cultivation will also increase. Forest land will be put to use in different ways creating other used patterns such as semishifting cultivation, shifting cultivation, and settlement areas. Forest deterioration can be prevented by giving people the opportunity to make profitable use of the forest so that they can earn a living comparable to that earned through cultivating crops. Therefore, the development of livestock production, such as with goats and sheep, is integrated with the forestry system.

CASE STUDY: GOAT RAISING UNDER MIXED DECIDUOUS FOREST

A flock of 41 goats at 800 m elevation, Ban Om Hae, Hod district, Chiang Mai province, was used as a case study. The

Table 3. Forest area (km^2) of Thailand by region, 1982.

Forest type	Northern	Northeastern	Eastern	Central and western	Southern
Evergreen	25568	930	6216	12449	14323
Mixed deciduous	25006	2618	1113	5192	-
Dry dipterocarp	34318	13819	253	540	-
Mangrove	-	-	418	335	2179
Pine	2018	144	-	-	-
Shrub woodland	846	-	-	-	-
Total	87756 (56.04%)	28886 (16.53%)	8000 (5.11%)	18516 (11.82%)	16442 (10.50%)

Source: Naiyanet (1984).

flock consists of 2 bucks, 17 does, and 22 yearling kids of local breed. The average mature weight is 55 and 38 kg for bucks and does, respectively.

The goats were raised grazing and browsing in an area of about 80 ha (0.8 km^2). The area is identified as 70% mixed deciduous forest and 30% abandoned swidden. The main forest tree species are as follows: *Shorea obtusa* Wall., *Shorea siamensis* Miq., *Dalbergia floribunda* Roxb., *Tectona glandis* L.f., *Cratoxylum maingayi* Dyer., *Bambax anceps* Pirre., *Terminalia chebula* Retz., *Phyllanthus emblica* L., *Dillenia* spp., *Gmelina arborea* Roxb., *Quercus brandisiana* Kurz., *Lagerstroemia speciosa* (L.), *Paramichellia baillonii* Hu., *Morinda tomentosa* Heyne ex Roth., *Hopea odorata* Roxb., *Baccaurea sapida* Muell. Arg., *Cassia tora* L., *Mangifera longipetiolata* King., *Dimocarpus longan* Lour., *Phylanthus emblica* L., *Vetex pinnata* L., *Schleichera oleosa* (Lour.) Oken., *Bauhinia racemosa* Lamk., *Bauhinia variegata* L., *Pinus kesiya* Royle ex Gordon, and *Pinus merkusii* Jungh-de Vriese.

The main undergrowths within the mixed deciduous forest are as follows: *Bambusa arundicacea* Willd., *Bambusa tulda* Roxb., *Thyrsostachs siamensis* Gamble, *Imperata cylindrica* Beauv., *Eulalia siamensis* Bor., *Casearia flexuosa* Craib., *Euphorbia coccinea* Roxb., *Phoenix acaulis* Ham., *Acroceras munroanum* (Balansa) Henr., *Morinda tomentosa* Heyne ex Roth, *Acacia rugata* Merr., *Paederia* spp., *Leersia hexandra* Sw., and *Eupatorium odoratum* L.

The abandoned swidden in mainly covered with shrubs and grasses. The wide range of plant species found in the abandoned swidden are as follows: *Eulalia siamensis* Bor., *Leersia hexandra* Sw., *Sida rhombifolia* L., *Solanum torvum* Sw., *Imperata cylindrica* Beauv., *Eupatorium odoratum* L., *Thysonolaena maxima* (Roxb.) O.K., *Solanum incanum* L., *Acroceras munroanum* (Balansa) Henr., *Agcratum conyzoides* L., *Bambusa arundinacea* Willd., *Bambusa tulda* Roxb., and *Thyrsostachs siamensis* Gamble.

Goats were kept in stalls overnight and were let out for grazing at about 0900. They were allowed free access to the forest and abandoned swidden and returned to the stalls in the late evening. During the day, one woman occasionally tended the flock to know where they were. The animals grazed and browsed year round in the area. Rice bran was used as supplement feed during the dry season (February to April). A bone meal and salt ratio of 2:1 was given twice a year. The flock was never vaccinated but was dewormed once.

Dry matter yields of grasses, climbing plants, and shrubs in the forest and abandoned swidden have been estimated by sample cuttings. Grasses and grasslike plants were cut short close the ground. The leaves and small twigs of climbers and shrubs were cut about 1 m from the ground. Each sample area covered 2 m^2 and there were 15 sample cuttings in total. This sample cutting was done during the rainy season. The estimated dry matter yield of the available forage was about 2.4 t/ha and that of the crude protein (CP) was 8.33%. The dry matter yield under rubber and coconut was 480-500 and 800-1200 kg/ha, respectively (Devendra and McLeroy 1982). The crude protein content under rubber and under coconut on a dry matter basis was 14-16 and 8-12%, respectively. In the hot, dry seasons, the dry matter yield of forage was difficult to estimate. There was rather limited forage in this period. Drinking water was also a problem. Dried leaves, sprouts, shoots, pods, and tree fruits were eaten by the flock. Fruits of the following trees were available: Mangifera longipetiolata King, Phyllanthus emblica L., Gmelina arborea Roxb., Phoenix acaulis Ham., Eugenia leptalea Craib., Acacia rugata Merr., and Irvingia malayana Oliv. ex A. Benn.

Productivity of the flock compared with a flock in a Chiang Mai suburb is shown in Table 4. In this mixed deciduous forest environment, the performance of the goats was not different from the goats raised in the Chiang Mai suburb.

Although the goats were never vaccinated, no serious disease-related problems were found. During the windy and cold period, the animals often caught cold and developed a cough. External parasites found in the area were sucking lice (Linognathus spp.), blood-sucking flies (Chrysops dispar), and leeches (possibly Haemadipsa zeylanica). This leech is found only in the nose of mammals, i.e., dogs, goats, cattle, and buffalo, and is contracted by drinking from infested water holes. Within 1 year, the number of deaths totaled six kids and one doe. The deaths were the result of dog bites. The dogs that were responsible were from other villages and followed the owners while they collected forestry products such as bamboo shoots, honey, etc. According to flock owners, dogs are a serious problem in goat raising in the area.

This preliminary study indicates that the major constraint to this system is the limited availability of forage during the

Table 4. Productivity of the case study goat flock and the Chiang Mai suburb flock.

Description	Case study flock ($\overline{X}$)	Chiang Mai suburb flock ($\overline{X}$±SD)
Litter size	2 (7)	1.6 (71)
Weight (kg)		
Birth	1.9 (4)	1.7±0.4 (111)
6 months	14.0 (4)	12.8±2.8 (16)
1 year	23.8 (3)	22.2±2.4 (7)

Note: Values in parentheses are the number of observations.

hot, dry season from February to mid-May. From late April to May, the availability of forage is not as serious a problem because during this period there are many sprout shoots or seedlings and by proper management of the stocking rate and supplementation of feed, the problem can be reduced further. Theoretically, goats could lose weight during this time, and compensatory weight gain should be expected in the next rainy season. Another problem is whether the browsing habits of goats can affect the regrowth of the forest; for example:

- The forest is often burnt by the villager to facilitate trekking across the forest and collecting the forest products, i.e., mushrooms; this practice has more of a negative impact on regrowth than the browsing of goats;

- Normally, the sprout shoots and seedlings selected by goats are undergrowth plants; these plants have little chance of reaching full growth, but they have very limited economic value and timber production is not threatened; and

- Proper management can also avoid overbrowsing of a given area.

CASE STUDY: SHEEP RAISING UNDER TEAK PLANTATION

The sheep flock of this second case study has been developed over the past 2 years at Ban Tung Prao, Maesarieng district, Mae Hongsorn province. This program was supported by the Karen Christian Church in cooperation with the Baptist Mission. There were 3 rams, 12 ewes, and 10 lambs in the flock during the observation period. The purpose of sheep raising is to provide meat, cash income, and fleece for clothing. The sheep were genetically heterogenous and were identified as being of local origin.

The sheep were penned at night and were tended by a shepherd while they grazed for 8-9 h/day. The flock grazed and browsed in the teak plantation during the cropping period (June to September). From October to May, after harvesting ended, fields were also used as grazing areas. During this period, rice bran was supplemented to about 15-20 kg/day. The supplementation of rice bran had been done since last October. The estimated grazing and browsing area was about 24 ha under teak plantation and about 2 ha of cultivation area. The teak plantation belongs to the government, and the trees had been planted for more than 5 years. The main undergrowths within the teak plantation were identified as *Dioscorea esculenta* Burk., *Paederia linearis* Hook.f., *Acroceras munroanum* (Balansa) Henr., *Pueraria mirifica* Airy Show and Suvatabhandu, *Croton oblongifolius* Roxb., *Wrightia tomentosa* Roem and Schult., *Lagerstroemia* spp., *Bauhimia* spp., *Terminalia* spp., *Dalbergia* spp., and *Salmalia* spp.

The sheep live weight at different ages was compared with other flocks (Table 5). There was no apparent difference in the performance among these flocks. Lambing occurred at all times of the years and, as is common with many tropical sheep, seldom produced twins. Shearing was done once a year during the hot, dry season. The estimated fleece yield of the flock was 1 kg/head. The sheared fleece was sold to the Karen Church at a price of 25 THB/kg (25 Thailand baht (THB) = 1 United States dollar (USD)) and was used by the church to make shirts and blankets, both for home use and for sale as handicrafts. A shirt needs 300 g of fleece and 200 g of cotton, but, for a single blanket, the material needed is about 3 times that of a shirt. The local Thai sheep produce a very hairy fleece estimated to be 70-90% hair and 10-30% wool (Coop 1976).

Because the supplemented feed was given to the flock during the period when little forage is available, the health

Table 5. Sheep live weight at different ages.

Age	Case study flock ($\overline{X}$)	Chiang Mai flock ($\overline{X}$±50)
Birth	1.6 (3)	1.9±0.4 (28)[a]
3-5 months	10.0 (1)	9.5±1.3 (9)[b]
6-8 months	12.0 (1)	14.9±3.4 (30)[b]
12-15 months	18.0 (1)	27.9±4.5 (17)[b]
>2 years		
Ram	35.0 (1)	30.1±4.1 (11)[a]
Ewe	24.5 (4)	26.2±5.3 (37)[a]

Note: Values in parentheses are the number of observations.

[a] Personal observation.

[b] Adapted from Hoare et al. (1976).

of this flock was generally improved and the lamb mortality was significantly decreased. Dog attacks occurred often and caused the death of three lambs and one ewe in the last 6 months. The shepherd of this flock recognized dog biting as the main problem. In other respects, the general health of the sheep is good.

The limitation of available forage during the hot, dry season has a strong impact on the sheep performance. Although the case studies on goat and sheep raising cannot be compared, it seems that goats can more easily adapt to such situations. In a hot environment, goats pant at half the rate of sheep, do not sweat, and lose less water in their feces and urine (Devendra and McLeroy 1982). From these observations, it was learned that sheep prefer grazing in the open areas to the forest. The sheep grazed in the forest for shorter periods than they did in the open areas. A capable shepherd is essential for the proper care and safeguarding of the animals.

The success of integrating small ruminants and deciduous forest depends on proper management during the hot, dry season. The careful manipulation of the stocking rate with available dry matter production, and feed supplementation are also important considerations. Goats should be able to adapt better to the system than sheep.

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DISCUSSION

The second session dealt with country case studies, issues, and problems with a view to demonstrating the different ecological zones, types of production systems, and prevailing patterns of management of small ruminants. These were highlighted in 10 country case studies that were most interesting in reflecting the range and variety of issues.

The first five papers of Session II dealt with integrated crop or tree production systems with small ruminants in five countries: Nepal, South India, Sri Lanka, Bangladesh, and Thailand. Unlike the subsequent regional papers, these five dealt with the smallest of the smallholders in systems approaching subsistence, while the following five papers considered, to some extent, larger production units with more capital and a greater emphasis on profit rather than subsistence.

The first paper described the environment (topography and climate) of Nepal and the varieties of livestock and production systems that are used to exploit this environment, which ranges from tropical lowlands to alpine. S.L. Pradahn showed that the products of sheep and goats are different from what is produced in some other environments and include

- Manure, of great importance;
- Carpet wool, which imposes restrictions on the fleece types of any sheep imported to crossbreed with the local sheep; and
- The unique use of sheep and, to a lesser extent, goats as beasts of burden in the high country of Nepal.

It was emphasized that feed supply was very limited and overgrazing was causing great erosion problems, both by wind and water. Overgrazing is caused by sheep in the high country, where sheep account for 75% of the small ruminant population. Yet, Nepal wants more sheep since wool imports are 3-4 times wool production.

The second paper described the geography and climate of south India and went on to describe the production systems in great detail. Milk and manure were significant outputs of these systems, as well as meat. A summary of Dr Mukudan's main recommendations to improve the production system included

- More extensive systems should be replaced gradually by more intensive systems, involving maximum use of by-products and less conventional feedstuffs;

- The system of grazing under the canopy of tree crops should be improved, fodder trees should be included in forestry schemes, and legislation should be implemented to protect pasture lands from overutilization;

- A system for improving the genetic capability of stock should be developed using artificial insemination where appropriate; and

- Cooperative societies should be formed to implement animal health programs, supply of resources such as feed, and marketing of products.

In Sri Lanka, distribution was influenced mainly by climate, with small ruminants in drier areas. A major portion of the diets of both species is provided by browsing scrub. For sheep, there is only one local breed, the Jaffna, which is being crossbred with temperate zone sheep.

For goats, many breeds have been crossed with the local goats; these have been Asian or African breeds. The Boer goat seems to offer great potential according to preliminary results.

Dr Rajaguru emphasized the need for the development of integrated crop - small ruminant systems rather than scrub grazing alone. Government policy has previously had the effect of suppressing the development of such systems. Recent policy changes permit and encourage small ruminant production, but it is necessary to develop both breeds and systems anew.

The fifth paper described the geography and systems of goat production in Bangladesh. Goats are owned by the poor sector of the population; cattle and buffalo by the rich. As living standards have dropped over the last decade, goat numbers have increased and large ruminants have decreased.

There is virtually no unutilized land and less than 1% is available for grazing.

The local Black Bengal goat is used in a wide variety of systems, over 20 different patterns of usage having been defined. One major product is meat, for which the price has risen recently, but to a smaller degree than the price of beef.

The other major product is goat skins: the skin of the Black Bengal goat is recognized as being of the highest leather quality available and foreign exchange earnings from skins rank third among exports. Skin exports have almost doubled in the last decade, while cattle hide exports, in number and total earnings, have declined.

The major problem is availability of feed. Several strategies to improve feed quantity and quality were suggested:

- More use of rice cropping by-products, conservation of crop residues as log or silage and reduction of use of straw as fuel and their replacement by wood;

- Processing and supplementation of straw to counteract nutritional inadequacies and increase intake;

- Use of agroindustrial by-products such as sugarcane tops and molasses, with the addition of urea to molasses; these off-farm by-products may come at too high a price for the smallholder; and

- Growth of leguminous trees and forages, in particular the use of trees as shade for other crops in the growing season, followed by harvest in the dry season.

The Black Bengal has significant disease resistance, skin quality, and flavour of meat characteristics, which may be lost in crossbreeding programs. The area of genetic improvement is confined to "within-breed" selection for this reason. Imported breeds have been tried and found to be lacking in these areas. Far more work is needed on this breed. Jamnapari were imported in the 1940s, and some remnants of these imports can be found.

Management is at subsistence level: goats often share houses with their owners, they are fed household scraps, and are herded by women and children. All goats are infested with roundworms, liver fluke, and often mange (which damages the valuable hide). If herd numbers increase above 20, disease morbidity and mortality increase.

Goats are the livestock of the poorest people, with the lowest resource availability for goat nutrition and health. They are tough, prolific, and appear to merit considerable research effort to improve production. Women and children play a particularly important role in goat production as they are involved in taking the goats to foraging and in keeping them close to the house at other times. Goat mortality appears to be lower when the animals are managed in small household flocks.

The sixth paper in Session II presented results of a small study of goat and sheep production in the open forests of northern Thailand. The government policy is for preservation of the forest, rather than clearing for agriculture, and this policy allowed the initiation of a study of alternative forest utilization and income generation. The results showed that goats performed better than sheep. The goats covered a much greater distance in the forest and, thus, may have had access to a greater range and amount of forage plants. Goats presented a herding problem and both species suffered from predation by domestic dogs from other villages. No information about environmental degradation is yet available.

INTEGRATION OF SMALL RUMINANTS WITH RUBBER AND OIL PALM CULTIVATION IN MALAYSIA

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Abstract *The feasibility of integrating small ruminants with oil palm and rubber cultivation is reviewed in relation to the resources that are available within the plantation sector. Earlier reports and current progress suggest that sheep are more compatible than goats when reared under a semi-intensive system in oil palm and rubber areas. In view of this, sheep are being experimented with on a large scale and preliminary results are very promising. A lambing rate of about 80%, with 85% singles and 15% twins, is obtained with 8-month lambing intervals. Growth of crossbreds has been most encouraging, with a daily gain of up to 120 g recorded when the lambs are supplemented with concentrate feeds. However, the experiences strongly highlighted the lack of technical information in the industry. These constraints are discussed with the view of achieving a rapid development in integrated small ruminant production systems in Malaysia.*

Malaysia has achieved self-sufficiency in the production of eggs, poultry, and pork. However, enhanced development in animals and the dairy industry is currently being actively pursued. This is in view of a projected increase in demand with an improved standard of living, an increased population, and requirements for a wider choice of meats. Several livestock-production systems have been investigated and the results, which show the development of livestock through integration with plantation crops such as rubber and oil palm, are very promising. This paper reviews the status, concept, progress, and constraints in the development of integrated livestock-production systems, with particular reference to goat and sheep production.

STATUS OF SMALL RUMINANTS

Goats and sheep are synonymous to the small ruminant industry in Malaysia. It is often described as a small, disorganized enterprise mainly because the animals are reared by smallholders with 1-2 ha of land. The farm is characterized by small flock size with low levels of productivity. This is particularly so because most farmers are agriculturists and the limited available land is usually "prioritized" for crop cultivation. This leaves the remaining area, if any, for livestock production. Under these circumstances, goats and sheep survive mainly by foraging crops and pastures in and around villages, wastelands, irrigation banks, roadsides, or crop areas.

These situations, coupled with lack of support and basic infrastructures, adversely affect the growth of the industry: over the last 20 years, the population has dropped slightly for goats and increased slightly for sheep (Table 1). Both goats and sheep, however, have a long association with the Malaysian rural economy. Furthermore, the importance of small ruminants is exemplified in demand and in recent developments in the production system. Demand is significantly large and is projected to increase substantially during the next 15 years (Department of Veterinary Services 1984). Based on a price of about MYR 12.00/kg carcass weight (in 1986, 0.772 Malaysian ringgits (MYR) = 1 United States dollar (USD)), the small ruminant industry is projected to grow from its present value of about MYR 80 million to MYR 136 million by the year 2000 (Table 2). Recent developments in the production system suggest that sheep and, to a lesser extent, goats may be integrated with the cropping system.

CONCEPT AND POTENTIAL OF INTEGRATION

The integrated or "zero-land" livestock-production system was formally discussed in Malaysia in the late 1970s (Abraham et al. 1978). The concept is to develop the livestock industry without having to depend on new land for pasture production. In this context, it may be defined as exploitation of untapped or underutilized resources within the present set-up for the production of livestock.

The resources and their direct and indirect relationship with the development of livestock industry is illustrated in Fig. 1. The primary objective is to establish a cost-efficient and effective production system for crops as well as animals. The system (Fig. 1) demonstrates that the feeds, which are the most critical factor in ruminant production, may be made available at a lower cost than the conventional, monoculture animal-production system. These potential feed resources may be categorized as undergrowth, cultivated pastures, and agro-by-product.

Table 1. Goat and sheep population (x 10^3) in Peninsular Malaysia, 1965-1984.

Year	Goats	Sheep
1965	308	37
1970	333	38
1975	329	45
1980	312	59
1984[a]	274	60

Source: Malaysia Department of Statistics.
[a] Interim values.

Table 2. Current and projected demand and value of beef and mutton in Malaysia.

	Cattle/buffalo			Sheep/goat		
Year	Demand (t)	Head ($\times10^3$)	Estimated value (MYR$\times10^6$)	Demand (t)	Head ($\times10^3$)	Estimated value (MYR$\times10^6$)
1985	27530	157.3	275.3	6735	500	80.8
1990	33500	191.3	335.0	8015	600	96.2
1995	40000	228.6	400.0	9540	710	114.5
2000	50000	285.7	500.0	11350	840	136.3

Source: Department of Veterinary Services (1984).

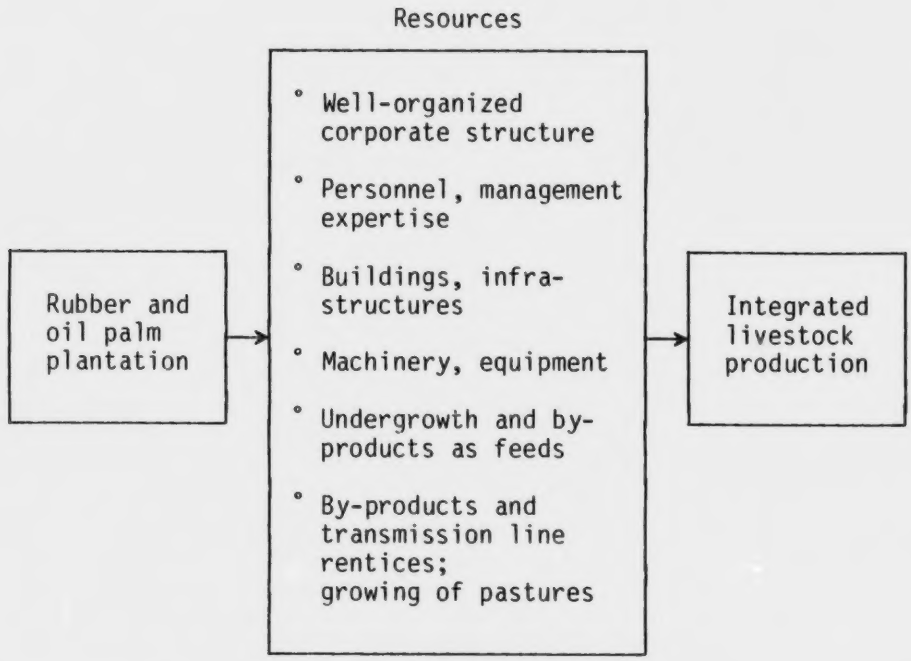
Resources
Rubber and oil palm plantation
° Well-organized corporate structure
° Personnel, management expertise
° Buildings, infrastructures
° Machinery, equipment
° Undergrowth and by-products as feeds
° By-products and transmission line rentices; growing of pastures
Integrated livestock production

Fig. 1. Available resources in the plantation industry.

Undergrowth

The undergrowth or ground vegetation forms part of the ecosystem of oil palm and rubber cultivation. This complex mixture of flora is generally classified under cultivated leguminous covers, grasses, and broad-leaved plants.

The botanical composition, yield, and quality of undergrowth is constantly changing because of the tremendous influence of many interacting factors. These factors include agronomic management, types and ages of main crops, soil types, rainfall, and terrain. A clear distinction in botanical composition is commonly observed between the estate and the smallholding because of differences in agromanagement practices. For example, the cultivation of cover crops in the ratio of 3:3:1:1 (*Pueraria javanica* - *Calopogonium muconoides* - *Calopogonium caeruleum* - *Centrosema pubescens*) is carried out by all estates but not by smallholders. This could be substantiated by earlier assessment showing the ground vegetation under estate management to have a higher percentage of leguminous cover than smallholding ground vegetation, particularly where the trees are less than 5 years old (Wan Mohamed 1977).

The age of the tree crop has also been shown to have a marked influence on the botanical composition of ground cover in both the oil palm (Fig. 2) and rubber (Fig. 3) plantations. The cultivated legume covers (excluding C. caeruleum) tend to decline and account for less than 20% of the total herbage yield about 3 years after planting. Besides botanical composition, the dry matter yield declines rapidly when the rubber is more than 3 years old (Fig. 4). A similar trend was reported for the ground vegetation under oil palm (Chen and Othman 1983). This is due to shading by the tree crop, which reduces the photosynthetically active radiation reaching the ground vegetation.

Although more experimental evidence is required to optimize undergrowth utilization, Mahyuddin et al. (1978) and Devendra (1982) noted that Malaysia's demand for lamb and

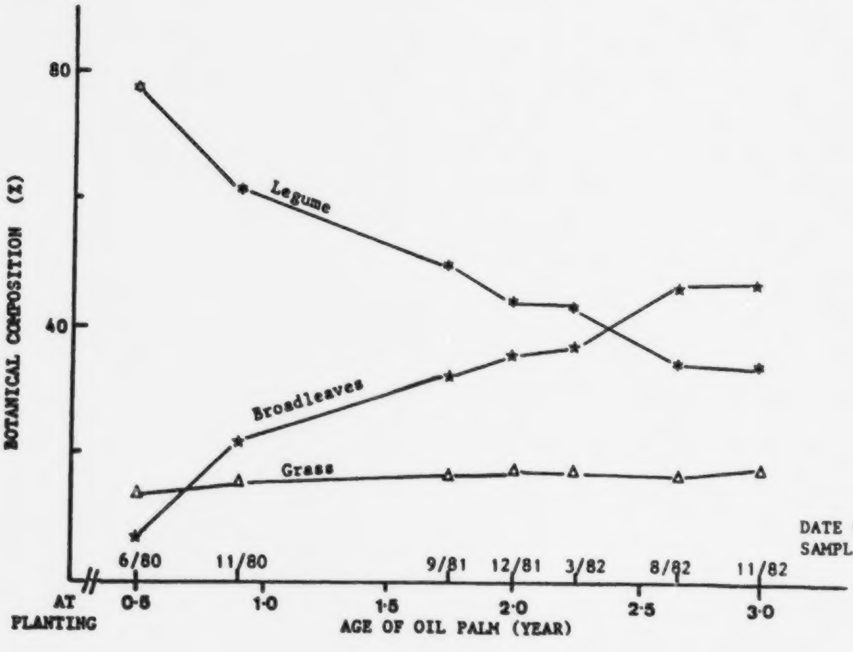

Fig. 2. Changes in botanical composition in relation to age of oil palm (adapted from Chen and Othman 1983).

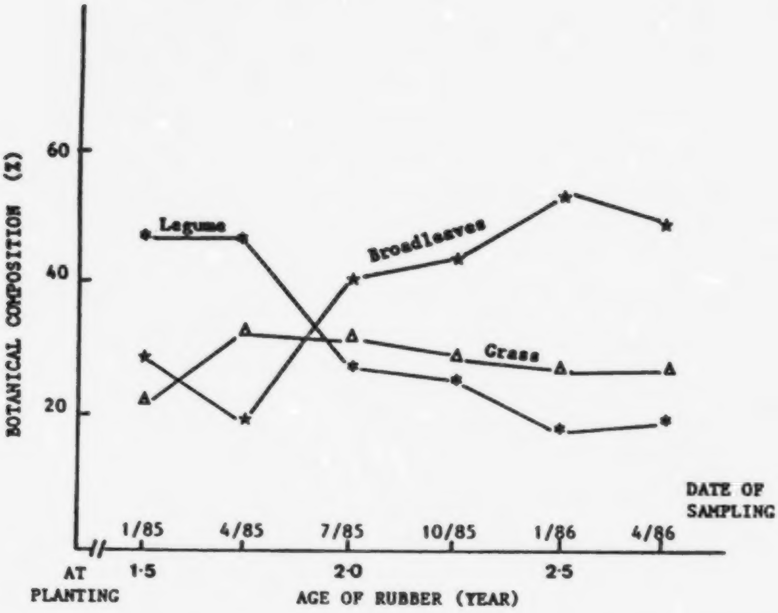

Fig. 3. Changes in botanical composition of ground vegetation in relation to age of rubber.

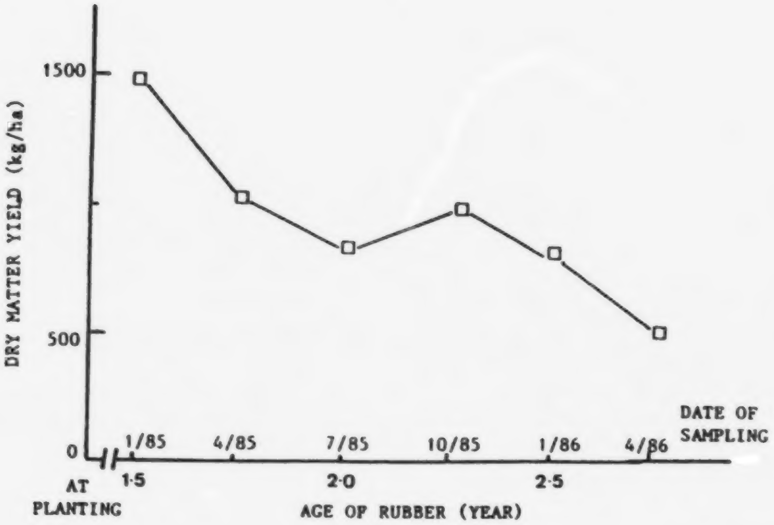

Fig. 4. Dry matter availability of ground vegetation in relation to age of rubber.

mutton could easily be met by using the herbage under 2.8 x 10^6 ha of rubber and oil palm.

Cultivated Pastures

Pasture cultivation under an integrated system is mainly aimed at achieving specific objectives such as

- Production of fat lambs or fattening of store lambs before finishing;
- To optimize the use of land that is not cultivated with tree crops; and
- To optimize the use of rubber and oil palm effluent as a primary source of fertilizer, thereby increasing stock-carrying capacity and reducing costs of effluent treatment.

These considerations, however, are suitable only for estate operation where land is not limited or utilized for specific reasons. For example, a census of Kumpulan Guthrie's Estates, one of the biggest plantation companies in Malaysia, showed 1.25% or about 1050 ha of the total area was not cultivated because of a number of factors (Table 3). Assuming that 50% (525 ha) of the uncultivated area is suitable for pastures (average annual yield, 20,000 kg/ha), an additional 15,000 to 20,000 sheep or goats may be produced annually.

Table 3. The status and size of vacant land in Kumpulan Guthrie, Malaysia.

Status	Size (ha)	Percent
Vacant (no reason)	442.8	41.12
Powerline rentices	140.0	12.90
Swamp	410.0	38.05
Acid sulphate	84.2	7.93

The other important consideration for pasture cultivation under an integrated livestock-production system is the use of rubber and oil palm effluent as fertilizer. Our trials at Guthrie Research Chemara (GRC) (Pillai and Tan 1977) showed highly satisfactory dry matter and crude protein yields from two grass varieties fertilized with rubber skim and mixed effluents (Table 4). Work on the use of oil palm effluent in pastures is in progress and preliminary results are promising (GRC 1986).

Table 4. Effects of rubber skim and mixed skim effluent on annual dry matter (DM) and crude protein (CP) yield (kg/ha) of napier grass (Pennisetum purpureum) and star grass (Cynodon plectostachyus).

Grass variety	Treatment	DM	CP
Napier grass	No fertilizer	16850	3020
	Compound fertilizer[a]	42380	6950
	Skim effluent[b]		
	10 mm RE[c]/month	51550	10100
	20 mm RE/month	50400	10500
	30 mm RE/month	57200	12450
Star grass	Compound fertilizer[a]	33800	4220
	Mixed effluent[b]		
	25 mm RE/month	42600	6600
	50 mm RE/month	46100	7600

Source: Pillai and Tan (1977).

[a] $N-P_2O_5-K_2O$, 17:8:17, at an annual rate of 6400 kg/ha (napier grass) or 5540 kg/ha (star grass).

[b] Skim effluent (kg/ha): N,667; P_2O_5,91; K_2O,610; MgO,18; CaO,16. Mixed effluent: N,150; P_2O_5,30; K_2O,130; MgO, 16; CaO,40.

[c] Rain equivalent.

Agroby-product

The potential and availability of agroby-products as animal feed have been extensively reviewed by a number of workers (e.g., Devendra 1978; Hutagalung 1978; Jaafar and Khusahry 1983; Lim 1983); the most significant potential is in the oil palm industry. This is mainly because of the amount of by-products produced annually. A diagramatic illustration of oil palm yield and its derivatives is presented in Fig. 5. Palm press fibre (PPF), palm oil mills effluent (POME), and palm kernel cake (PKC) form the most important source of feed. Realizing the area of land under oil palm production, the potential availability of oil palm by-products during the next 5 years is high and, therefore, important in supporting the growth of the animal industry (Table 5).

COMPATIBILITY AND PROGRESS OF INTEGRATION

The potential and compatibility of integrating small ruminants with oil palm and rubber cultivation have been stressed on numerous occasions. These topics were given particular attention during the seminar on integration of animals with plantation crops, held in Penang, Malaysia, in 1978.

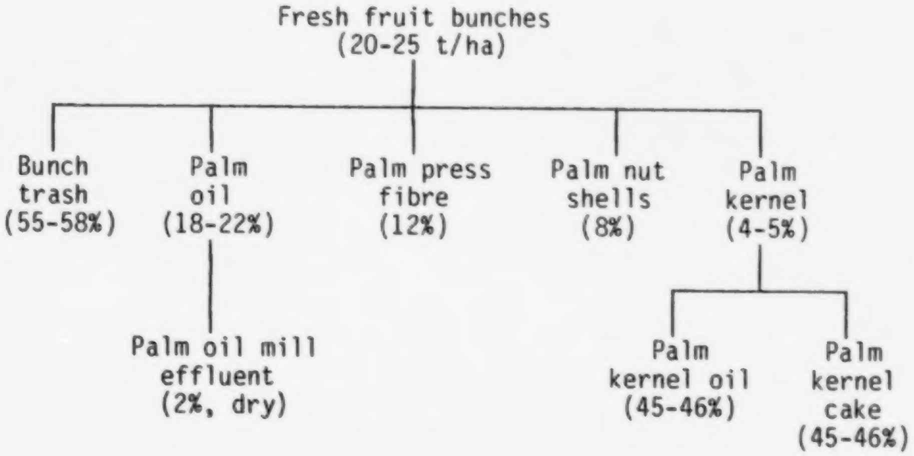
Fresh fruit bunches
(20-25 t/ha)
Bunch trash (55-58%)
Palm oil (18-22%)
Palm press fibre (12%)
Palm nut shells (8%)
Palm kernel (4-5%)
Palm oil mill effluent (2%, dry)
Palm kernel oil (45-46%)
Palm kernel cake (45-46%)

Fig. 5. Principal products and by-products of oil palm fresh fruit bunches.

Table 5. Estimated availability (t) of oil palm by-products in Malaysia, 1986-1990.

Year	By-products[a]		
	PKC	POME	PPF
1986	560	88	2750
1987	600	96	3000
1988	650	104	3250
1989	700	112	3550
1990	770	120	3750

Source: R.I. Hutagalung, University Pertanian Malaysia, Serdang, Malaysia, personal communication, 1986.

[a] PKC, palm kernel cake; POME, palm oil mills effluent; PPF, palm press fibre.

From 1975 to 1981, the Rubber Research Institute of Malaysia (RRIM) evaluated goats reared under rubber cultivation. Their biological performance (Table 6) is comparable with those reared under monoculture systems; however, their compatibility with tree crops depends largely on the type of management. The semi-intensive system (a system that is commonly practiced in Malaysia where the animals are herded to graze during the day and back to the homestead (shelter) in the evening) is not very suitable because

- Goats tend to graze and browse over wide areas; a permanent paddock system is costly because of a low carrying capacity, the cost in herding and mustering the animals is high;

- Damage to young areas, particularly debarking of rubber trees and browsing of palm fronds, is common; and

- Where goat is suitable, e.g., under mature areas, the ground vegetation is sparse and, therefore, a larger area and more labour are required to muster the animals.

Because of these limitations, alternative systems such as stall or semistall feeding must be investigated.

Table 6. Reproductive performance of goats under two systems of production.

Biological index	Integration[a]	Monoculture[b]
No. of offspring per dam per year	1.75	1.65
Kidding intervals (days)	259	259±22
Single kids (%)	79.4	35.5
Multiple kids (%)	20.6	64.5
Birth weight (kg)	1.34	1.50
Daily weight gain (g) up to 3 months	77.5	66.7
Kid mortality	31.2	NA

Note: NA, not available
[a] Mean from two farms. Source: Lee et al. (1978).
[b] Source: Devendra (1983).

Sheep have been reported to be more compatible with rubber and oil palm cultivation than goats. Earlier work by the RRIM with farms ranging from 20 to 400 breeding ewes (Wan Mohamed 1977, 1978, 1982; Tan and Abraham 1982; Wan Mohamed and Hamidy 1983) showed that sheep are not only useful in complementing the use of herbicides and reducing costs of weeding, but also in increasing returns per unit area of land. In view of this, Kumpulan Guthrie pioneered a large-scale research and development investigation in integrated sheep-production systems. Two upgrading and multiplication farms, each with 1000 breeding ewes, were established between 1984 and 1985.

The results over 18 months have been most encouraging. Parturition and lamb performance (Table 7) are comparable with earlier reports by RRIM. Singles were most common and

Table 7. Parturition and lamb performance index between mid-1984 and March 1986.

	Locals, May 1984[a]	F_1 crossbreds			
		Feb. 1985[a]	July 1985[a]	Oct. 1985[a]	March 1986[a]
Ewes tupped	NA	580	470	650	455
Births	439	427	371	529	325
Lambing (%) (normal births)	NA	73.6	78.9	81.4	71.4
No. of lambs	474	445	379	565	333
Singles	404	365	317	437	283
Twins	70	80	62	128	50
Prolificacy (%)[b]					
Singles	92.0	90.6	91.6	87.9	85.0
Twins	8.0	9.4	8.4	12.1	15.0
Birth weight (kg)	1.32	2.06	2.29	2.36	2.15
Singles	1.46	2.18	2.39	2.42	2.55
Twins	1.10	1.46	1.55	1.67	1.61
Mortality (%) (preweaned)	67.3	23.8	6.1	4.1	1.8
Singles	63.4	20.0	4.4	1.8	0.7
Twins	90.0	41.3	14.5	11.7	8.0
Stillbirths	33	21	12	11	16
Abortions	17	3	2	10	5

Note: NA, not available.

[a] Lambing period.

[b] Prolificacy = $\frac{\text{no. of single or twin births}}{\text{total births}}$.

accounted for about 85% of the total births. A significant improvement in lamb birth weight and survival rate were obtained with crossbreeding and improved management. Growth of F_1 crossbreds is most encouraging and far superior than that of the local indigenous breed. Furthermore, the crossbreds were found to be responsive to supplementation with high-energy diets (Fig. 6) and may be "finished" at an age of about 8-10 months.

CONSTRAINTS AND SUGGESTION IN INTEGRATION

The constraints of integration are somewhat similar to the development of small ruminant industry in Malaysia. They are very evident in all aspects of production and marketing.

Breeding and Selection

The genetic resources of our goat and sheep populations are too limited for a rapid development of the industry. The lack of official breed characterization, especially in the case

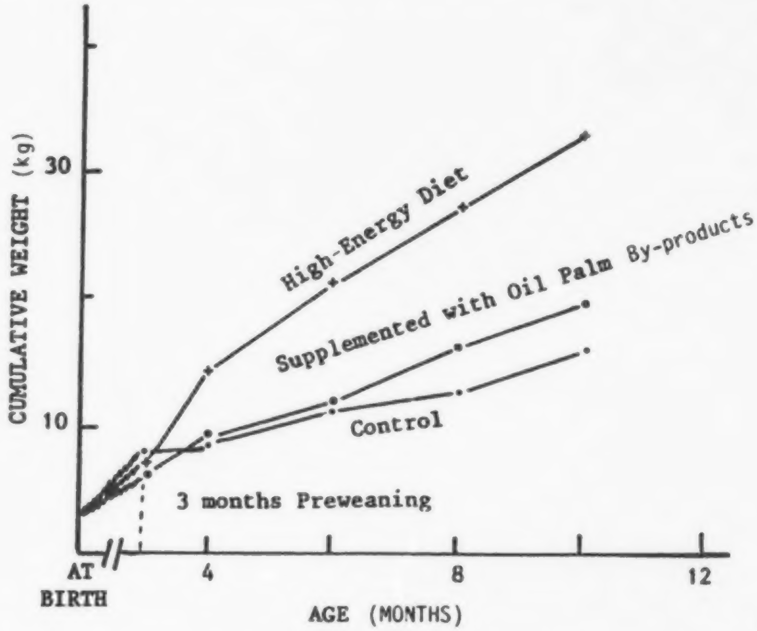

Fig. 6. Growth of F_1 crossbred with three types of supplemented feeds.

Table 8. Factors affecting availability and utilization of feed and feed resources with integration.

Feed and feed resources	Availability, production	Utilization
Ground vegetation	Reduces rapidly with increasing age of tree crops	Not accessible to stock when trees/palms are young
	Competition with animals from neighbouring farms	Herbicide spray of tree crop planting rows
	"Wide" area of coverage, thus reducing grazing time, increasing security risk, and wasting energy and time in herding and mustering	Rat baiting (only under oil palm)
Cultivated pastures	The suitability of pasture species	No major problems
	Availability and distribution of nonutilized lands	
	Availability and distribution of rubber and oil palm effluents for pastures	
Agroby-products	No major problems	Low-quality, particularly PPF and POME
		High copper concentration in PPF, POME, and PKC, which leads to copper toxicity problems

of sheep, is hampering the national breeding policy and breeding programs. Also, the availability of does and ewes is limited and, therefore, selection for breeders is based on availability rather than quality. The other factor that limits the progress of upgrading and multiplication is the choice of exotic sire breeds. Little attention is given to this factor and, therefore, potential breeders are subjected to high risk factors.

Health and Diseases

Health is one of the most important areas that affects small ruminant production. Losses because of ill health and disease have not been quantified in economic terms, but the experiences at Guthrie's Estates (Wan Mohamed 1986) showed major problems in endoparasites and ectoparasites, pneumonic pasteurellosis, enterotoxemia, meliodiosis, *Escherichia coli*, contagious karatoconjunctivitae (pink eye), and contagious ecthyma. Pneumonic pasteurellosis is most common and causes the high mortality among lambs and newly purchased adults.

Treatment of bacteria-related diseases such as pneumonic pasteurellosis using antibiotics often fails to give satisfactory results. This is due to the difficulties in identifying the affected animals during early stages of infection. Because of this, a national flock health and disease-prevention program must be introduced. Vaccination to combat common diseases has to be examined to prevent potential losses.

Feed and Feed Resources

The availability and management of feed and feed resources are critical in integration. For example, the ground vegetation that forms the primary source of feed in semi-intensive systems of production is highly variable in terms of quality and yield. The problem is more acute in the smallholdings and small estates (<250 ha), where the tree crops are generally planted in one phase.

Although the problem is less critical under estate operation, the availability and utilization of feed and feed resources is considered critical to production. Some of the major problems are described in Table 8. Intensive research involving feeding of oil palm by-products to small ruminants is essential.

Processing, Advertising, and Marketing

Apart from the establishment of abattoirs in some areas of the country, other strategies such as processing, marketing, and public campaigns have not significantly increased consumption. Therefore, to stimulate and promote sustained growth of the small ruminant industry, the country has to formulate concerted efforts in marketing.

CONCLUSIONS

The "zero land" or integrated livestock production system offers exciting possibilities in the development of an efficient and productive farming system in Malaysia. However, large-scale development of the industry under integration will have to be preceded by sound practical field research and development programs. An area that urgently requires examination is the problem of disease, especially as related to large farm operations. Metabolic and other health problems that are related to feeding of oil palm by-products should also be given priority. Earlier reports and current progress, however, suggest that sheep and, to a lesser extent, goats may be successfully integrated into the rubber and oil palm industry.

ACKNOWLEDGMENTS

The author wishes to thank Kumpulan Guthrie Sdn Bhd for giving permission to publish this paper, and Dr Mohd Aminuddin Mohd Rouse, Controller, Guthrie Research Chemara, for his keen interest and comments.

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INTEGRATED SMALL RUMINANT AND TREE-CROPPING SYSTEMS IN INDONESIA

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Abstract *Sumatra has large areas of plantation crops. By using the weeds found in plantations, productivity can be increased in terms of profitability from livestock and from reduced weed-control costs.*

Plantation weeds or planted cover crops in rubber production can be used as a ruminant feed. The nutrient quality of the weeds is low and the palatability of cover crops is marginal. Quality of weeds can be improved by planting high-quality or high-producing forages in the interrows. Replacing weeds with cultivated grasses does not affect rubber production. Legumes that are good-quality livestock feeds appear to give the same stimulus to rubber production as do more traditional legume ground covers.

Another way to improve the quality of plantation forage diets is through the use of other by-product supplements that are produced in Sumatra: e.g., rice bran, coconut meal, cassava meal, molasses, and oil palm by-products. Individual by-products are inherently imbalanced and must be combined with other feeds to provide a balanced diet. Rumen-fermentable nutrients appear to be in shorter supply in tropical forages and feeds than they are in temperature environments. The feeding of concentrates is not always economical; therefore, economic analyses must be done as frequently as possible to determine minimum and optimum economical levels of feeding.

Sheep and goats are relatively easy to raise; they are prolific, have a ready market, a low maintenance cost, and a low initial investment; they are also capable of converting crop residues into high biological value food. These advantages have resulted in small ruminants being widely distributed in Indonesia. They are mostly kept in villages by smallholders (4,180,000 householders). The total small ruminant population in 1979 was 11 x 10^6 head or 57% of the total ruminant population (Biro Pusat Statistik 1983). The goat population is apparently higher than the sheep population in all provinces. Of the countries in the Association of South East Asian Nations (ASEAN), Indonesia has 95% of the sheep and 80% of the goats. Within Indonesia, Sumatra has only 3% of the sheep and 10% of the goats. Most of the people and the highest concentration of small ruminants are found in Java. The average annual population increase for sheep and goats in Indonesia from 1974 to 1982 was 3 and 2.6%, respectively. These rates are higher than the human population growth rate of 2.3% per year.

SMALL RUMINANT PRODUCTION SYSTEMS IN INDONESIA

Small ruminants are reared in traditional ways in Indonesia. Some animals are continuously confined to small, raised, wooden animal houses, whereas others are grazed during the day and brought home at night or when it rains.

Traditional small ruminant barns in Indonesia are well designed and particularly well adapted to the environment. In Sumatra, roofs are made of palm fronds or alang-alang (*Imperata cylindrica*), walls are woven bamboo or wooden boards, and floors and supports are often split palm trunks or bamboo. Floors are raised at least 1 m off the ground, allowing easy collection of manure (usually composted and put on crops) and reducing the humidity inside the barn (Ketaren et al. 1984).

More than 6.6 x 10^6 ha were under crops in Indonesia in 1975, about 86% of which was owned by smallholders (Harimurti 1978). Therefore, the crop-animal system is of special importance to small farmers. As cropping has intensified, lands that were formerly used as off-season pastures are double cropped.

Perennial tree crops, such as coconuts, oil palm, and rubber, occupy land for as long as 50 years. Competition for nutrients from annual and perennial weeds is a continuous problem. Alternatives include pulling or cutting the weeds by hand; however, these procedures are very expensive and laborious, and must be done four or five times per year. Grazing improves weed control and some benefits are realized from crop production increases as a result of manure deposited by grazing animals.

INTEGRATING RUMINANTS WITH RUBBER PLANTATIONS

Large areas of Sumatra are used for plantation crop production, mostly rubber and oil palm. Generally, the current policy forbids any livestock to graze plantation areas. Therefore, estates do not keep livestock, nor do they officially sanction the use of estate lands for livestock production.

Smallholders are responsible for 82% of the total rubber production in Indonesia. In Sumatra, 1.5 x 10^6 ha is devoted to smallholder rubber (Direktoral Jeneral Perkebunan 1984). Since 1977, the government has been developing new rubber-based transmigration schemes. Problems with these schemes have arisen because there is no income during the relatively long lag time (about 6 years) between planting and rubber production. Food can be planted in the interrows for 2 or 3 years, but then follows a period of stress when the farmer must either make a living from an outside job or from farming other land. Plantations are often neglected during this time. Undergrowth is dominated by uncontrolled alang-alang and shrubs (Prawiradiputra et al. 1979). Weeds compete with trees for soil nutrients, especially nitrogen. Tree growth is slowed, bark becomes thin and white, time to first tapping is delayed, and lifetime production of the plantation is severely reduced.

Forage is most plentiful in the pretapping years of the plantation; however, varying amounts of forage are available throughout the lifetime of the plantation. With this in mind, a project was started in 1985 at Sungai Putih, North Sumatra, that was jointly sponsored by the Small Ruminant Collaborative Research Support Program (USA), the Animal Research Institute of Indonesia, and the Rubber Research Institute of Indonesia. Two flocks of 40 sheep were grazed in 7-year-old, newly tapped plantations. Forage production in these plots was probably the lowest that it would be during the lifetime of the plantation (Fig. 1). Two more flocks of 44 sheep were grazed in a mature, 13-year-old plantation.

Of the three leguminous cover crops planted when the plantations were established, only *Pueraria javanica* remained. *Pueraria javanica* has been found to be relatively acceptable to sheep and goats (Ginting et al. 1987); however, it did not persist well under heavy grazing and disappeared from the plots within 6 months.

Grasses, especially Paspalum conjugatum, were grazed preferentially by sheep and persisted fairly well. Other broad-leaved vegetation, such as Mikania micrantha, a moderately acceptable species (Ginting et al. 1987), persisted very well. It was found that overall forage value was severely limited by unpalatable or marginally palatable species. Production was also limited because the recovery of many species appeared to be directly related to the amount of incident sunlight. Slowness of recovery reduces carrying capacity and, if rotational grazing is practiced, will lengthen the required rest period.

According to Dahan et al. (1978), energy rather than protein is likely to be the limiting factor in rubber-grazed pastures. Accordingly, the 168 project sheep were placed on

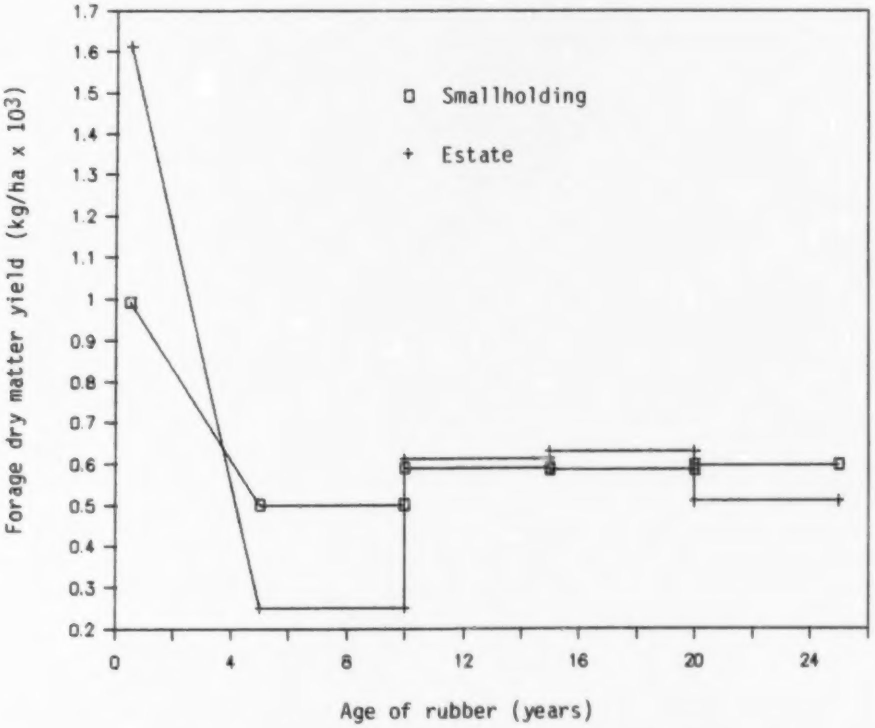

Fig. 1. Estimated forage dry matter yield in relation to age of rubber (adapted from Wan Mohamed 1977).

four treatment diets based on increasing levels of energy with protein held constant. Supplements were mainly rice bran, with cassava meal and molasses added to increase energy levels. Fermentable and bypass protein were balanced in the diets by adding small amounts of urea and fish meal. Supplements were fed at 0, 0.6, 1.0, and 1.4% of average flock body weight.

Sheep were purchased as lambs and, during the first 6 months, growth rates of the four treatment groups were 37, 48, 57, and 64 g/day, respectively. During the second 6 months, reproductive parameters were studied. Supplementation resulted in a significant drop in mortality rates of newborn lambs: 25, 12, 0, and 6%, respectively. In addition, the highest level of energy supplementation resulted in significantly more twins being born: 32, 44, 16, and 59%, respectively. The overall effect of supplementation is evident from the weight of lambs weaned during the first 13 months of the project: 83, 185, 227, and 300 kg, respectively (Handayani and Reese 1987).

In addition, data on rubber production, soil fertility, and soil compaction have been monitored. First-year results indicate that sheep are not adversely affecting rubber production or soil characteristics (Reese et al. 1986). The study is being continued for a 2nd year to arrive at firmer conclusions.

Because weed species frequently have low nutritive value, one solution is to plant improved grass or legume species. Sheep may disturb young rubber trees; therefore, during the first couple of years, trees would need to be protected by baskets. Improved forages must be established before shading reduces germination rate, probably before the 3rd year after planting.

It is also possible to use interrows for cattle zero-grazing systems. During the past year, the Rubber Research Institute at Sembawa, South Sumatra, has initiated a project using Bali and Bali-cross cattle that are fed *Setaria plicata*, a high-yielding grass that has been planted in the rubber interrows.

Earlier research in South Sumatra was carried out by Ba'as (1983) using improved species planted in rubber tree interrows. Forages were cut for cattle. Ba'as found that improved grasses produced significantly more dry matter than volunteer grasses (90% *Axonopus compressus*) under immature rubber. Annual dry matter production was 16,000 kg/ha for Pennisetum purpureum and 13,000 kg/ha for Brachiaria decumbens, compared with 5000 kg/ha for the A. compressus plots. There was, however, no significant effect on trunk girth increase of the immature rubber trees. A subsequent experiment under mature rubber trees again showed that there was no significant difference between improved and volunteer grass species in their effect on rubber production.

The legumes used in the experiment under immature rubber were less productive than the improved grasses, but Stylosanthes guianensis yielded the same as A. compressus, 5000 kg/ha per year. The yield of Centrosema plumieri was lower than that of S. guianensis, 2000 kg/ha per year; however, both legumes increased the rate of trunk girth growth. This shortened the time to first tapping by 5.5 months, probably by sparing or providing nitrogen. Under mature trees, rubber production was also significantly increased in legume plots.

Rubber estate plantations frequently plant cover crops, mainly Pueraria javanica, Pueraria phaseoloides, Calopogonium muconoides, and Calopogonium caeruleum (Nasution 1985). These legumes shade out alang-alang and other weeds, reduce erosion, and provide nitrogen to the trees. The two Calopogonium species are particularly low in palatability (Ginting et al. 1987), although C. caeruleum palatability may be improved by wilting (D. Ffoulkes, personal communication).

It may be that rubber productivity can be maximized by planting legumes in rows flanking the trees. The centre of the interrow could be planted with high-yielding or high-quality grasses. The width of the interrow and the tree spacing could be increased to support more livestock.

Generally speaking, forage production under mature rubber is insufficient to economically justify maintaining cattle (M. Ba'as, personal communication). Sheep can be grazed in mature plantations, provided that pastures are managed to prevent overstocking. To foster adequate regrowth, on-hand volunteer species should not be allowed to drop below 800-1000 kg/ha.

FEED CONSTRAINTS

Rumen-fermentable nutrients are in much shorter supply in the tropics than in temperate regions. In tropical pastures, ruminants will eat out the grass before the legumes. They do this even though tropical grasses are generally higher in fibre and lower in quality than temperate grasses. Because, in temperate climates, animals generally preferentially graze legumes, the inescapable conclusion is that tropical legumes are relatively unpalatable.

Why would this be true? One possibility is that where there is no winter dieback from environmental plant pathogens, plants have evolved chemical and physical pathogen barriers. Structures or chemicals that slow or prevent bacterial attack in the environment will probably slow or prevent bacterial attack in the rumen. This problem is compounded as varieties of crops that are more pathogen resistant, such as rice, are developed, because of the possibility of by-products or stubble being more resistant to rumen fermentation.

Logically, supplementary feeding would be needed to provide rumen-fermentable nutrients. This contrasts with temperate feeding, where fermentable nutrients are generally abundant and supplementing with bypass nutrients is emphasized.

Fermentation of by-product feeds is often retarded by processing with heat or chemicals, so that nutrient quality is frequently highly variable depending on the processing technique utilized. By-product feeds found in Sumatra include rice bran, coconut meal, oil palm by-products, cassava meal, and molasses.

Rice bran, the feed most commonly used as a concentrate supplement in Sumatra (Pulungan et al. 1985), is very resistant to rumen breakdown. In animals fed a basal diet of sugarcane, nearly 60% of the rice bran dry matter remained in the nylon bag of a rumen-fistulated cow after 24 h; only 22% of the nitrogen and 58% of the starch had disappeared (Ffoulkes 1985). Most of the nitrogen and a lot of the starch had bypassed the nylon bag. Copra cake, maize, and cassava tuber were much better sources of fermentable nutrients: 60-70% of the nutrients were apparently utilized in the rumen.

A second constraint of by-product feeding is that by-products are incomplete feeds. Not only is rice bran poorly utilized in the rumen, it also has a very poor calcium-phosphorus ratio. To properly evaluate its feed potential, the bone mineral ratio must be corrected with shell meal, limestone, or a high calcium - low phosphorus feed such as molasses, which is also high in fermentable carbohydrate.

Cassava is also widely grown in Sumatra. Both leaves and meal from roots can be used as animal feeds. Leaves are high in protein but may also be high in cyanide-producing compounds. Cassava meal is high in starch and has virtually no protein. On Sumatra, all cassava is used for human consumption, although "washings" from cassava production are occasionally used for feeding livestock. Cassava is not commercially available for feeding animals.

Sugarcane is also raised on a commercial basis in Sumatra. The processing plant in Medan, North Sumatra, produces 30 t molasses per day. Molasses is high in readily fermentable carbohydrate and calcium but has no protein. The major problem regarding molasses is handling. In liquid form, it is awkward to handle; blocks require fairly controlled cooking temperatures. The Medan sugar factory is considering making molasses - rice bran pellets. If pelleting is feasible, molasses - palm kernel meal may also be a good combination. Currently, molasses is not commercially available in Sumatra as a livestock feed.

Oil palm by-products show great potential as livestock feeds. Studies at the Animal Research Substation at Sungai Putih showed that growing sheep supplemented at 1.5% of body weight with palm kernel cake reached gains of 100 g/day (Ketaren et al. 1985).

Smallholders are responsible for a greater proportion of coconut production than any other plantation crop in Indonesia (95%, 3×10^6 ha). The quality of coconut meal is highly variable. Its energy level is dependent on the effectiveness of the expelling process. Protein availability is dependent on the temperatures used in processing as well as the method of processing. Coconut meal is generally available in feed stores in Sumatra.

How should feeding guidelines for tropical situations be developed? Feed tables do not give fermentable versus bypass nutrient values. In any case, those values may be highly dependent on basal diet, and the whole concept of feed tables will be disrupted (D. Ffoulkes, personal communication).

It is commonly suggested in the tropics that concentrate feeding does not pay for itself. This is probably related to the lack of fermentable nutrients and other problems previously mentioned. Daud and Yusuff (1983) fed rice bran or coconut meal at 1% of body weight to sheep grazing under rubber trees.

Sheep supplemented with rice bran showed an economic loss of 5% when compared with unsupplemented sheep; however, sheep supplemented with coconut meal demonstrated a 57% economic advantage over unsupplemented sheep.

The sheep involved in the rubber project in Sungai Putih, North Sumatra, showed similar results, although in terms of reproduction (lambs sold) rather than growth. During the first 13 months of the project, 33% more lambs were weaned by ewes supplemented with rice bran than by unsupplemented ewes. However, when molasses and cassava meal were added to the rice bran, ewes weaned almost 90% more lambs. Ewes supplemented with rice bran showed an economic loss of 17% when compared with unsupplemented ewes; however, ewes supplemented with molasses-cassava demonstrated a 20% advantage over the unsupplemented ewes. The increase in number of lambs weaned in ewes supplemented with rice bran was due to a sharp decline in preweaning mortality rate, indicating that the ewes were producing stronger lambs and more milk. Ewes supplemented with the higher level of fermentable carbohydrates combined with same low lamb mortality rates with a significantly higher twinning rate than any of the other dietary groups. Therefore, the increased energy supplementation had increased ovulation rate or embryo survival.

CONCLUSIONS

Intensifying agricultural production on Sumatra by integrating livestock and plantation crop production is receiving a lot of attention. Grazing sheep can help control weeds on estates and provide income to smallholders during critical pretapping years. Forages that tolerate shading, are persistent under grazing, and provide adequate rates of gain need to be located and tested. Optimum carrying capacities for different-aged plantations should be determined. It appears that government policymakers in Sumatra are relatively open minded and that, with adequate data, policy will be altered to allow sheep to graze in plantations.

The problems of using supplementation to obtain adequate growth and reproduction rates are more complex than expected. By-product feeds, unlike whole plants or seeds, are not complete, and nutrients must be balanced before the potential of the feed can be evaluated. In addition, nutrition research will probably have to focus on providing the rumen-fermentable nutrients required.

In formulating research programs in Indonesia, one should keep in mind that Indonesian farmers are already part of the money economy. Research needs to focus on small-scale commercial production to maximize benefits to both the smallholder farmers and the burgeoning city populations.

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INTEGRATION OF SMALL RUMINANTS WITH COCONUTS IN THE PHILIPPINES

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Abstract *Farming in the Philippines today is basically a smallholder occupation. Ninety percent of coconut farmers are smallholders with less than 5 ha of land. To sustain an average farming family, optimization of resources is necessary and integration becomes the natural resource. Considering the* 3.217×10^6 *ha of coconut land nationwide in 1984, the potential of integration is tremendous. Integration of small ruminants with coconuts should be emphasized, if only to increase the income of most coconut farmers and, at the same time, to maximize the utilization of available resources. The 2,362,000 goats (1984) and 30,000 sheep (1983) provide a considerable livestock base to support livestock integration in coconut lands. Small ruminants are most appropriate in the traditional coconut farms, coconut-crops farms, coconut-pasture (livestock) farms, or a mixture of these production systems. Preliminary indicators show that the integration of small ruminants serves to complement and adjunct copra yield to as high as 260 kg/ha in coconut-pasture (livestock) farms and that small ruminants readily convert to meat and manure-fertilizer crop products, crop by-products, and pasture available under coconuts. The added value contributed by the integration of small ruminants can proportionately increase the income of the average coconut farmer.*

The economic recovery program of the Philippines today is anchored in agriculture, which remains the mainstay of the country's economy, with about 11.75×10^6 ha devoted to food crops and commercial crops. Approximately 90% of the livestock raisers, primarily those engaged in smallholder ruminant production, subsist mainly on forage-pasture, weed, crop residues, and other by-products of crop lands. Commercial grazing lands, composed of improved or unimproved arable and nonarable areas with considerable silvipastures, account for 1.2×10^6 ha, with a potential carrying capacity of 425,000 animal units (AU; 1 AU = 1 adult cow = 5 adult small ruminants) (Mendoza 1985).

Food crop areas in 1984 totaled 7.74×10^6 ha, with a predominance of corn and rice. The average landholding of food crop farmers was 1.3 ha. In the same year, commercial crop areas covered 4.01×10^6 ha, with coconut as the predominant crop, 3.22×10^6 ha, or 80.2% of the total commercial crop area (PCA 1985). Most coconut farmers are smallholders: those with less than 2 ha constituted 70.1%; those with 2-5 ha constituted 20.8%; and those with more than 5 ha accounted for 9.1% of coconut farmers (Eleazar 1981). In the last decade, coconut products suffered from a low international market value and the competition of copra substitutes. The majority of the coconut farmers who depended mainly on copra production had to shift to multistorey and multiple cropping under coconut and the integration of livestock (Baconawa et al. 1985).

Integration of livestock with coconuts has shown increasing importance in recent years. The potentials of integrating livestock with coconut farms are tremendous considering the continuously increasing areas of coconut in the country (Table 1).

In the province of Zamboanga del Sur, Philippines, 135,600 ha, or 43% of the total provincial agricultural area, is devoted to coconuts. Households whose main income comes from copra or corn own the highest percentage of all types of livestock (Synnot 1979). Synnot's survey showed that pastures were grown mainly after crops, under coconuts or tree crops, or on uncultivated land. The survey further indicated that more than 90% of goats were on farms of less than 2 ha. This, in itself, suggested that small flocks were common and small-scale subsistence production was typical throughout the province (Hitchcock 1985). This further suggests the role of small ruminants as a potential livestock base for integration into crops, primarily coconut.

The small ruminant population has been particularly dynamic in the past decade; the number of goats has tripled from 1976 to 1984 (Table 2) (BAE 1985). Sheep, as a component of the small ruminant population, are estimated to number 30,000 (FAO 1983). The significant increase of small ruminants, primarily goats, and their predominance among small farmers indicate their increasing importance as an integral part of existing smallholder farming systems.

Table 1. Area planted to coconut, 1976-1984.

Crop year	Area (x 10^3 ha)
1976	2521
1977	2714
1978	2890
1979	3064
1980	3126
1981	3105
1982	3162
1983	3187
1984	3217

COCONUT AND SMALL RUMINANT PRODUCTION SYSTEMS

The production farming systems in coconut farms are classified as traditional (with indigenous herbage growth), coconut-crops, coconut-pasture (livestock), or as a mixture of these.

The integration of small ruminants into the existing coconut production farming systems has been predominantly in the villages, the extensive, and the semi-intensive feeding systems as described by Devendra (1984), where goat ownership can range from 1 to 15 head and feeding management can vary from the traditional tethering and extensive grazing to the more recent semiconfinement with minimal concentrate feeding. Intensive and very intensive production systems under coconut are gaining popularity among coconut farmers who have more than 15 goat or sheep and who are inclined to breeder production and goat dairying.

SMALL RUMINANT PRODUCTION IN TRADITIONAL COCONUT FARMS

About 1 x 10^6 ha, or about 33% of the total 3.217 x 10^6 ha of coconut land, is classified as traditional coconut farms and these are covered by native or indigenous grasses and legumes (Table 3). Moog et al. (1977) noted that native pastures growing under coconuts in the province of Batangas are made up

Table 2. Livestock and poultry inventory (x 10^3), 1976-1984.

Year	Carabao	Cattle	Hog	Goat	Chicken	Ducks
1976	2725	1737	6489	785	45671	4104
1977	2897	1723	5696	1104	45289	4228
1978	2959	1820	6910	1290	58892	5365
1979	2803	1833	7445	1374	49320	5338
1980	2870	1883	7934	1671	52761	4725
1981	2850	1940	7758	1696	57724	4783
1982	2908	1651	7795	1783	59710	4905
1983	2946	1938	7980	1859	62255	5419
1984	3022	1849	7613	2362	59205	5764

Source: BAE (1985).

of shade-tolerant grasses such as *Puspalum conjugatum*, *Setaria palmifolia*, and *Centrosema accresens*, with a predominance of leguminous plants such as *Alysicarpus*, *Desmodium*, *Pueraria*, and *Calopogonium*. These grasses and legumes are available throughout the year and provide the farmers with nutritious feed for livestock. When feeds are scarce, farmers use coconut frond stalk in addition to bamboo leaves, banana leaves, and *Glyricidia sepium*.

A study conducted in 1983 on the pasture domains and pastures of Zamboanga del Sur indicated that 50,000 ha, or 37% of the total 135,000 ha of coconut land in the province, is dominated by indigenous grassland and about 85,600 ha, or 63% of the total, is subjected to intercropping and cultivation.

Pasture studies in the Philippine Association of South East Asian Nations (ASEAN) Goat and Sheep Center (PAGSC) indicated an annual ovendry matter (ODM) yield of 4000-4360 kg from indigenous grasses and legumes under coconut. The pasture yield is distributed throughout the year, with the bulk from June to October and the lowest yield from March to May.

With the existing native pasture resources in traditional coconut farms yielding a conservative 4000 kg ODM/ha annually, it is estimated that 2000 kg (50%) is utilized by the grazing animal. Allowing 25% for wastage, it is computed that the net available annual yield is 1500 kg ODM/ha. Considering the

Table 3. Common grassland species under coconut.

Local name	Latin name
Calopo	*Calopogonium muconoides*
Lacatan	*Axonopus compressus*
Amor sico	*Chrysopogon aciculatis*
Wild bermuda	*Cynodon* sp.
Bila-bila	*Elucine indica*
Carabao grass	*Paspalum conjugatum*
Pandan	*Cyperus retundus*
Hagonoy	*Chromolaena odorata*
Moni-moni	*Desmodium* sp.
	Crotolaria gambiiensis
Yoya-yoya	*Alternathera* sp.
Limbagat	*Stachy tapetum jamaicensis*
Kanding-kanding	*Salvia* sp.
Burgensusa	*Mimosa pudica*
Sagbot	*Sida* sp.
	Minosa invisa
	Classia tara

Source: Sweeney (1984).

average mature weight of native goats and sheep of about 2 years of age (24.8 and 26.3 kg, respectively), the estimated carrying capacity per hectare of native pasture under coconuts is six goats or five sheep.

Small ruminant management systems under traditional coconut farms are predominantly under the village- and extensive-feeding systems. In a study of village cooperators by the PAGSC, average daily gains (ADGs) from day 1 to the end of the 1st year recorded for female native goat and sheep grazed under traditional coconut farms were 32.8 and 39.2 g, respectively. For the noncastrate male sheep, the ADG was 54.16 g. The ADG of female goats is lower than that found by Hitchcock (1985), who examined native goats on traditional village feeding management, and recorded an ADG of 44.3 g from 3 to 8 months of age.

Small Ruminant Production in Coconut-Crop Farms

About 2 x 10^6 ha of coconut farm is used for multistorey cropping, multiple cropping, and intermittent cultivation. Coconut farm utilization for undercropping is greater on Luzon Island than in the Visayas or Mindanao areas. A study on coconut undercropping in the province of Zamboanga del Sur revealed that the most commonly practiced cropping pattern was corn monoculture. Trials on the evaluation of cropping pattern were conducted in 1978 (Zamboanga del Sur Development Project 1980). Results indicated that the viability of tried patterns, in decreasing order of profitability, were rice-mungbean, corn-corn, corn-sorghum, corn-mungbean, corn-peanut, and mungbean-rice. Based on the study of Moog et al. (1977) in Batangas, the approximate annual ODM yield per hectare is computed assuming that 50% of the total dry matter yield is provided for feeding and that an allowance of 25% wastage is provided. These conservative assumptions were based on the practices of harvesting and utilization of crop by-products by coconut-crop farmers.

The carrying capacity of coconut-crop farms (Table 4) was based on mature weights of 24.8 kg for goat and 26.3 kg for sheep. The integration of small ruminants in coconut-crop farms can further raise the average income while utilizing the highly nutritious crop products and by-products. Carrying capacity of coconut-crop farms can be tremendously increased with appropriate harvesting procedures and proper storage and preservation of crop by-products. The availability of crop products as green feed peaks from June to October and is lowest from March to May. Integration of small ruminants in coconut-crop farms can vary from the village-feeding management to the semi-intensive and very intensive feeding system. Goats (0-6 months, 50% Anglo-Nubian x 50% native female) and sheep (0-5 months, native female) fed partly with crop by-products among village cooperators of the PAGSC showed ADGs of 69 and 54 g, respectively.

Small Ruminant Production in Coconut-Pasture (Livestock) Farms

A large proportion of coconut land is suitable for coconut-pasture (livestock) operations. The traditional coconut farms, which account for about 1 x 10^6 ha, can readily be transformed into coconut-pasture operations. Studies are being conducted at the PAGSC on pasture development under coconuts and its effect on copra yield (Table 5).

Table 4. Carrying capacity of coconut-crop farms under the different cropping patterns.

Cropping pattern	Approximate annual ODM (t/ha)	Net annual ODM available for feeding (t/ha)	Carrying capacity	
			Goat	Sheep
Corn-corn	12.3	4.6	17	16
Corn-mungbean	11	4.12	15	14
Corn-peanut	11	4.12	15	14
Corn-sorghum	12.3	4.6	17	16
Rice-mungbean	11	4.12	15	14
Mungbean-rice	11	4.12	15	14

Results of the coconut-pasture (livestock) trials indicate an increase in copra yield of 260 kg and a higher available annual ODM yield in pasture A, which is predominantly Setaria-Centrosema. This can be attributed to the higher proportion of Centrosema and the lesser competitiveness of Setaria. Pasture B, however, showed a remarkably decreased copra yield compared with the control (pasture C). This is attributed to the higher competitiveness and swarding effect of signal grass and the lesser proportion of Centrosema. Crossbred female goats (50% Anglo-Nubian x 50% native) grazed on a mixture of pastures A and B showed an ADG of 61 g, while native sheep grazed on the same pasture showed an ADG of 56.1 g for males and 43.5 g for females up to 1 year of age.

The botanical compositions of pastures A, B, and C are outlined in Table 5. Computation of carrying capacity (Table 6) was based on the annual ODM yield per hectare and the ODM requirements of mature native goats and sheep with average live weights of 24.8 and 26.3 kg, respectively.

The integration of small ruminants in coconut-pasture (livestock) farms is appropriate for the semi-intensive, intensive, and, partially, the extensive feeding system of management. The added value of goat and sheep and the use of animal manure as fertilizer can dramatically raise the income of coconut farmers in this type of operation.

Table 5. Production measurements in coconut-pasture (livestock) farm.

Kind of pasture	Annual (t ODM/ha) (cut every 35 days)	Annual (t ODM/ha) (cut every 70 days)	Annual copra yield (t/ha)
Pasture A			
Setaria sphacelata var. *splendida*	10.46	10.87	
Centrosema pubescens	4.05	4.40	
Others	0.11	0.18	
Total	14.62	15.45	2.36
Pasture B			
Bracharia decumbens var. *basilisk*	7.81	8.04	
Centrosema pubescens	2.89	3.25	
Others	0.06	0.12	
Total	10.76	11.41	1.56
Pasture C			
Native grasses[a]	4.00	4.36	2.10

[a] See Table 3 for botanical composition.

CONCLUSION

The dramatic increase in the population of small ruminants over the last decade presents an opportunity to coconut smallholders. The availability of small ruminants in the countryside, primarily goats, as compared with other livestock species provides a broader chance for their integration with coconuts. The low technology inputs, the versatility in the feeding habits, and the relatively low acquisition cost of goats and sheep can fit appropriately into the majority of smallholder coconut farms. Feed resources for small ruminants abound in coconut farms. Optimum utilization of these feed resources can

Table 6. Carrying capacity per hectare of coconut-pasture at 35- and 70-day cutting trials.

Kind of pasture[a]	Goat Grazing	Goat Cut and carry[b]	Sheep Grazing	Sheep Cut and carry[b]
Pasture A				
35 days	27	54	25	50
70 days	28	56	27	54
Pasture B				
35 days	20	40	19	38
70 days	21	42	20	40
Pasture C				
35 days	7	14	7	14
70 days	8	16	7	15

[a] See Table 5 for botanical composition of pastures.

[b] No wastage, and complete and efficient utilization of the forage is assumed.

be attained with the integration of small ruminants. The added value of goat meat and milk, mutton and wool, and animal manure as fertilizer produced from the use of crop product, crop by-product, and forage under coconut can raise the average income of the coconut smallholder.

ACKNOWLEDGMENTS

We thank the Project Management Committee, Bureau of Animal Industry, Philippine ASEAN Goat and Sheep Center, Manila, for their support and approval of this paper. Thanks are also due to the Ministry of Agriculture and Food, Region IX, for their support. Special thanks are extended to Mr Antonio Taclain, Mr Jose Curativo, Ms Betty Bayobay, Mr Francis L. Bagundol, and the PAGSC staff for their cooperation and data inputs. We also thank Ms Dionisia Tuble and Ms Angie A. Daniel for their typing. Lastly, thanks are extended to all those who, in one way or another, made this manuscript possible.

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DISEASE PROBLEMS OF SMALL RUMINANTS IN INDONESIA

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Abstract *Diseases of small ruminants are divided into three types: first, those of known economic significance; second, those of unknown economic significance; and, third, those of other livestock species in which small ruminants may play an important epidemiological role. Parasitic diseases are the most important in the first group, especially gastrointestinal nematodiasis and fascioliasis. These diseases can be controlled by chemotherapy and sound management, and extension services to farmers need to be improved to maximize economic return. The second group includes a number of diseases and more research work is required to ascertain their importance. In the third disease group, small ruminants play an important epidemiological role in foot-and-mouth disease of large ruminants and malignant catarrhal fever (sheep only) of Bali cattle and buffalo. The control of some of these diseases and future research requirements are discussed.*

There are about 8×10^6 goats and 4×10^6 sheep in Indonesia. Of this population, about 85% is on the island of Java, which is only 9% of the total land mass of the country (Biro Pusat Statistik 1984). Both species are kept with minimal land requirements by smallholders or landless farmers in villages. There is a strong correlation between the population densities of humans and small ruminants (Tillman 1981); around 20% of all farms in Indonesia have small ruminants (Knipscheer et al. 1983). Small ruminants are kept for a variety of purposes including meat, milk, wool, cultural and religious functions, manure, and as a source of "liquid" money (Fletcher 1984). There are two main breeds of goat (Kacang and grade Ettawah) and three main breeds of sheep (Javanese thin tailed, Priangan, and fat tailed). Goats are important components of some transmigration schemes.

There are few detailed studies on the epidemiology and economics of diseases of small ruminants. Rangkuti et al. (1984) listed 18 diseases of goats and Thedford et al. (1984) produced a goat health handbook for Indonesian farmers that contains notes on a large number of diseases that may occur in Indonesia. Ronohardjo et al. (1985) attempted to divide diseases of small ruminants into those thought to have some significance and those known to occur but whose significance is unknown. Of the former group, parasitic diseases are the most important.

This paper describes and reviews the main diseases of small ruminants in Indonesia and concentrates on diseases of some significance. Diseases of other livestock in which sheep or goats play an important epidemiological role are also mentioned.

DISEASES

Diseases of small ruminants in Indonesia are divided into three groups (Table 1). Group A includes important diseases, which are listed here and in Table 1 in order of suggested economic importance; group B consists of other diseases known to occur; and group C includes diseases that are important in other livestock species and involve small ruminants as possible carriers.

Group A

Gastrointestinal nematodiasis

This disease complex is caused by a number of nematode parasites including Haemonchus, Trichostrongylus, Strongyloides, and Oesophagostomum. Of these, Haemonchus and Trichostrongylus are the most important. Much information on the effects that these parasites have on small ruminants has been obtained at the Research Institute for Animal Disease in Bogor. This research has been recently reviewed by Beriajaya and Stevenson (1986a). These studies showed that worm infestation was very common, but that the level of infestation could be influenced by rainfall and altitude, the feeding system, and pen construction. Higher helminth levels were found in small ruminants in low, wet areas, in animals using a fully grazed as opposed to a zero-grazed system, and in animals in pens with poorly designed floors that retain feces. Weight-gain improvement can be achieved by the administration of anthelmintics, but the choice of anthelmintic is very important. A study

Table 1. A summary of diseases of small ruminants in Indonesia.

Group A. Diseases of significance in suggested order of economic importance

- Gastrointestinal nematodiasis: parasitic, endemic, widespread, *Haemonchus* most important
- Fascioliasis: parasitic, endemic, widespread, *Fasciola gigantica* most important
- Mange (goats only): parasitic, endemic, widespread, *Sarcoptes scabei* most important
- Pneumonia: bacterial (precise aetiologies often uncertain), endemic, widespread, *Pasteurella* most important
- Plant intoxication: toxic or fungal etiology, sporadic

Group B. Diseases known to occur

- Virological: bluetongue (other Orbiviruses), contagious ecthyma (Orf), rabies
- Parasitic: primary myiasis (screw worm), secondary myiasis, coccidiosis
- Bacterial: anthrax, salmonellosis, tetanus, clostridia, foot rot

Group C. Diseases of other livestock involving small ruminants as carriers

- Foot-and-mouth disease: large ruminants, pigs
- Malignant catarrhal fever (sheep only): large ruminants
- Bluetongue

using different anthelmintics and different regimes on 636 small ruminants showed that significant weight gain occurred after the repeated use of broad-spectrum anthelmintics. Single doses of narrow- or broad-spectrum drugs were of limited value because of rapid reinfestation with larvae (Beriajaya and Stevenson 1986b); this study also showed that anthelmintic treatment could be cost effective. The annual cost of haemonchosis to the small ruminant industry in Indonesia has been estimated at around USD 16 million (Parsons and Vere 1984).

Fascioliasis

Two species of liver fluke, *Fasciola gigantica* and *Gigantocotyle explanatum*, can be found in the livers of small ruminants in Indonesia, with the former being much more important. Mixed infections can occur. *Fasciola gigantica* is more common in large ruminants than in small ruminants. The point-prevalence rates of flukes in the livers of cattle passing through the Bogor abattoir was 60.6% compared with 21.9% in sheep and 20.6% in goats (Suhardono 1984). This lower prevalence rate in small ruminants is probably due to management practices, because zero-grazed animals would not come into contact with the snail intermediate host. However, *Fascioliasis* in small ruminants is associated with acute disease and high mortality. Thus, this disease is economically important. Anthelmintics are rarely used to combat this disease because of expense, availability, and ignorance of possible economic benefit. Management practices should concentrate on systems that eliminate contact with the snail intermediate host.

Mange

Mange, which is due to *Sarcoptes scabei*, is common in goats but not sheep (Sangvaranond 1979) and can cause severe mortality in kids (Kertayadna et al. 1982). The disease can be treated with acaracides, but these are not always available and repeated treatment is necessary (Manurung 1986). The annual cost of mange to goat production in Indonesia has been estimated at USD 5 million (Parsons and Vere 1984).

Pneumonia

Pneumonias of different types are another common cause of death in both sheep and goats (Rangkuti et al. 1984). The etiologies are often uncertain; however, *Pasteurella* and *Mycoplasma* pathogens have been implicated. The prevalence of pneumonia is associated with climate and management. The disease is more common in the rainy season and in systems where crowded housing and poor nutrition are characteristics.

Plant intoxication

Diseases thought to be due to toxic plants occur sporadically and are relatively uncommon. The etiology of such diseases is often obscure. Ronohardjo (1981) reported a case of photosensitization in sheep that may have been associated with *Lantana camara*. Facial eczema of sheep has been reported (Murdiati *et al.* 1983) to be associated with feeding on *Brachiaria*. However, the fungus responsible for facial eczema, *Pithomyces chartarum*, has not been identified on *Brachiaria* grasses in Indonesia.

Group B

There is little accurate information on the epidemiology of most of the group B diseases. Antibodies to five types of bluetongue virus (1, 12, 17, 20, and 21) have been reported in sheep and goat sera collected from different parts of Indonesia (Indrawati et al. 1986); however, clinical bluetongue in sheep and goats has only been reported once (Sudana and Malole 1982.) Contagious ecthyma (Orf), which is caused by a pox virus, can be common in goats and uncommon in sheep. Feeding is difficult during the disease and young animals may die of starvation. Coccidiosis and foot rot have been reported in kids in wet areas, where they are heavily stocked (de Boer 1986).

Group C

Foot-and-mouth disease

In Indonesia, foot-and-mouth disease (FMD) caused by type O virus is thought to be mainly a disease of large ruminants and only these animals are vaccinated. However, in the last major outbreak in 1983, the clinical disease was observed in sheep, from which FMD virus was isolated (Young et al. 1985). Thus, small ruminants may play an important role in the epidemiology of this important disease.

Malignant catarrhal fever

A fatal type of malignant catarrhal fever (MCF) in large ruminants associated with sheep is widespread in some areas of Indonesia. Sheep-associated MCF has similar pathology and clinical signs to an African form associated with wildebeest, whose causal agent is a herpes virus (Snowdon and St George 1982). The etiology of sheep-associated MCF has not yet been established. However, there is a clear association with sheep, especially after lambing (Ramachandran et al. 1982). Sheep-associated MCF particularly affects Bali cattle and buffalo, with Bali cattle being the most sensitive species (Ginting 1979; Hoffman et al. 1984).

Bluetongue

The involvement of sheep and goats in bluetongue has already been mentioned. However, small ruminants may act as a reservoir for bluetongue in large ruminants: antibodies to the disease have been found in small ruminants (Sudana et al. 1982).

DISCUSSION

There is little doubt that diseases are major constraints to the sheep and goat industry developing to their full potential in Indonesia. Although there are good control measures available for all the important diseases, disease control by itself is of limited value and should be associated with management packages tailored to individual situations. The majority of farmers in Indonesia are smallholders or landless farmers and the numbers are increasing (Biro Pusat Statistik 1984). Most of these farmers have little knowledge of disease control and, thus, great efforts are required to mobilize extension services so that management packages have some chance of sound and beneficial application.

There is great potential for the further development of the small ruminant industry in Indonesia. The development of the sheep industry, however, is severely constrained because of the role of sheep in MCF in large ruminants. Thus, Bali cattle and sheep cannot be reared in the same areas; e.g., in West Java, a prominent sheep-rearing area, no Bali cattle are found. Emphasis is being placed on the Bali cattle industry in many areas of the country, especially Sulawesi and Timor; in these areas, sheep cannot be reared. There should be much greater potential for increased goat production and, in fact, this is occurring in some transmigration schemes.

Small ruminant research should be collaborative and concentrate on the development of improved production methods. Emphasis should be placed on disease control and nutritional systems, breed performance, and possible breed improvements.

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INTEGRATED SMALL RUMINANT AND CROPPING SYSTEMS IN FIJI WITH HEALTH AS A MAJOR CONSTRAINT

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Abstract *Sheep and goat meats are in high demand in Fiji and account for 80% of nonfish meat imports. The bulk of the estimated 183,000 goats in Fiji are raised by smallholder crop farmers growing sugarcane, rice, and coconuts. An estimated 27% of goats, however, are raised on larger commercial farms carrying 50–1500 head. Where goats are integrated with crops, they either graze the margins of cultivated land or under the canopy of tree crops. Few crop residues or by-products are utilized as feed. The major constraints on productivity are predation, theft, disease, seasonality of nutrition, complexity of marketing, and the relatively low level of husbandry skills of some farmers. Helminthosis is a particularly severe constraint on goat production.*

Technical innovations that are likely to lead to improved productivity include improved control of helminthosis, the use of improved pasture fodders and supplements to overcome seasonal feed shortages, the development of fully intensive commercial farming systems, the increased use of improved meat bloodlines, and, possibly, the introduction of cashmere as an alternative product.

The Fiji Islands are situated between 16 and 20°S and have a total area of 18,000 km^2, of which 67% is steep and mountainous (Twyford and Wright 1965). Only 18% of the land surface is suitable for arable crops and 30% is appropriate for grazing (Anon. 1982). Annual rainfall over most of the country varies from 1800 to 3200 mm. The human population at the end of 1984 was 691,000, comprising 45.2% native Fijians, 49.9% Fijians of Indian extraction, and 4.9% others (Anon. 1986a).

Both goats and sheep have been raised in Fiji since the 1840s, with goats being by far the more successful of the two species. At present, both are kept solely to provide meat, predominantly for the Indian component of the population.

Locally produced fresh goat and sheep meats are considered delicacies by the Indian population and, as a result, are highly priced compared with frozen imports. Animals are usually purchased live and taken home for personal slaughter and consumption. Less than 2% of the total estimated production is slaughtered in registered slaughterhouses.

By the end of 1985, there were an estimated 183,000 goats and 1,800 sheep in Fiji (Table 1). In 1985, the total estimated carcass production from goats and sheep was 644 t compared with import figures of 5250 t (Anon. 1985a). Sheep and goat meats formed 80% of Fiji's nonfish meat imports in 1985.

SMALL RUMINANT PRODUCTION SYSTEM

Goat raising in Fiji can be broadly classified as either smallholder or commercial on the basis of the size of the goat herd and its importance in relation to the overall farm operation. Since 1975, research and development efforts have concentrated on commercial farms carrying around 100 goats. It is presently estimated that some 50,000 goats, or 27% of the national herd, are kept on such farms, while 133,000, or 73%, are maintained on smallholdings (Walkden-Brown 1985).

Smallholder Goat Systems

The agricultural census of 1978 revealed that there were 14,942 holdings carrying goats, with an average herd size of eight: 31% of goats were reared on holdings under 1 ha, 45% were reared on holdings between 1 and 10 ha, and 24% were reared on holdings greater than 10 ha (Rothfield and Kumar 1980). It is probable that the proportion of goats on holdings greater than 10 ha is now 30% (Walkden-Brown 1985).

Goats maintained under the smallholder system are generally tethered in small groups or occasionally fenced. Herd size averages 6 or 7 and rarely exceeds 30. Goats are tethered by day on road verges, crop margins, vacant land, or

Table 1. Sheep and goat population and production data, 1978-1985.

Year	Goat population[a]	Estimated goat meat production (t carcass)	Goat meat imports (t carcass)	Sheep population[b]	Sheep meat imports (t carcass equivalent)
1978	121567	425	285	359	7002
1979	123000	432	242	NA[c]	5078
1980	129000	451	230	NA	4151
1981	143000	502	236	334	4909
1982	151000	529	247	757	3858
1983	161000	565	192	938	4307
1984	178000	623	136	1273	4860
1985	183000	641	173	1836	5078

Source: Annual Reports, Ministry of Primary Industries, Suva, Fiji.

[a] 1978, census values (Rothfield and Kumar 1980); 1979-1985, estimates.

[b] Government stations only; sheep on other holdings totaled less than 100 throughout the period.

[c] Not available.

communal grazing leases. In the evenings, they are brought home and either tethered around the house or securely penned.

The use of anthelmintics is generally not practiced, although worm burdens can be high. Supplementary feeding is rare. The goats are often inbred and the use of improved breeding stock is not common. Despite this, productivity is not as low as might be expected, because the animals are generally small, hardy, and fecund, and close supervision restricts losses as a result of predation and theft.

Commercial Goat Systems

It is estimated that there are some 50,000 goats on 500 holdings that can be classified as commercial because the goat enterprise is relatively large, occupies a considerable portion of the owner or manager's time, and contributes significantly to total farm income. Stock numbers on these farms range from 50 to 1500 with most carrying 80-150.

Commercial goat farmers may be specialist goat farmers or may run goats with beef or dairy cattle, under coconuts, or as an adjunct to sugarcane or rice farming. Goats on these farms are generally reared under either the semi-intensive or extensive husbandry systems.

Semi-intensive

This grazing system involves night yarding or housing every evening and some or all of

- Fencing in of stock;
- Supplementary nutrition or improved pastures;
- Regular drenching;
- Breed improvement;
- Stock segregation; and
- Indoor confinement of kids until weaning.

Extensive

In this system, animals graze large, fenced, or, more commonly, unfenced areas, without regular yarding or the inputs listed for the semi-intensive system. The extensive system is most common on islands or where goats are integrated with cattle or coconuts.

INTEGRATED SMALL RUMINANT AND CROPPING SYSTEMS

Fiji's economy is based largely on sugarcane and tourism. Important crops other than sugarcane include coconuts, rice, Caribbean pine, root crops, cocoa, maize, peanuts and pulses, and vegetables (Table 2).

The majority of goats in Fiji are found on crop farms. The 1978 census revealed that 46% of the national herd was found on sugarcane farms, 8% was on livestock farms, 3% was on coconut plantations, and 43% was on other holdings (Rothfield and Kumar 1980). Most of these "other holdings" would undoubtedly be small mixed-crop farms. In 1978, 53% of all sugarcane farms, 33% of coconut plantations, and 13% of all other agricultural holdings carried goats (Rothfield and Kumar 1980).

Table 2. Production and area under cultivation for the major crops in Fiji.

Crop	Area under cultivation 1984 (ha)	Total production, 1984 (t)
Annual		
Sugarcane	69000	480106 (sugar)
Rice	10442	22246 (paddy)
Root crops[a]	8400	73400 (various)
Maize	820	1900
Peanuts and pulses	676	274
Vegetables	550	4650
Tree		
Coconuts	87000[b]	24545 (copra)
Caribbean pine[c]	50500	20000 m^3 (sawn timber)
Cocoa	3550	245 (dry beans)

Source: Anon. (1984a), except where indicated.

[a] Taro (*Colocaisia esculenta*), cassava (*Manihot esculenta*), yams (*Discorea* spp.), sweet potato (*Ipomoea batatas*), and kava (*Piper myphisticum*).

[b] Source: Anon. (1985b).

[c] Source: Anon. (1984b).

Integration of Goats with Annual Crops

Sugarcane

Fiji has 22,130 sugarcane farms in the drier zones of the country; each farm has an average holding size of 3 ha. It is now estimated that 60% of these farms keep goats, holding 96,000 in all; average herd size is estimated at 7.

The majority of goats on sugarcane farms are managed on the smallholder tethering system. During the late growing period, goats may be run in the sugarcane field to control weeds, but this is not widely practiced. At harvest time, ruminant livestock from all farms in the area congregate on the farms being harvested to forage on fresh sugarcane tops. This provides an important source of ruminant nutrition during the May-November dry season, but is used more for cattle than goats. No fodder conservation practices are carried out. Total annual national production of sugarcane tops in Fiji is in the vicinity of 960,000 t fresh weight, although goat farmers have reported that the main variety of sugarcane grown in Fiji produces tops that are unpalatable to goats, especially when dried.

Other annual crops

The area used for annual crops other than sugarcane is 20,214 ha, compared with 69,000 ha for sugarcane. Of these other arable crops, rice is the major crop integrated with goat production. Rice is grown in both the dry and wet zones of the country and involves mainly Indo-Fijian farmers. Integration occurs on much the same basis as sugarcane, except that goats are never allowed onto the crop while it is growing. The goats are commonly tethered on rice stubble after harvesting for periods depending on whether one or two crops are grown per year. The use of rice straw to feed animals is rare; this is mainly because of the ready availability of green forages of higher digestibility.

Many vegetable and root crops are difficult to integrate with goats because their foliage is too palatable. Increasingly, village vegetable and root crop plots are being fenced against both cattle and goats. The use of fresh crop wastes such as cassava and sweet potato leaves to supplement goat feed does occur; however, in most cases, these wastes form only a small part of the overall diet.

Integration of Goats with Tree Crops

Coconuts

The 67,000 ha of coconut plantations in Fiji are mostly located in the lightly populated islands of the eastern and northern regions of the country. The plantations are generally run by non-Indians and are poorly located in relation to the major Indo-Fijian population centres in the western and central regions of Fiji. Nevertheless, an estimated 5% of the national goat herd is presently maintained on these holdings. Their main function is to weed under the coconuts, where they are run extensively with cattle on unimproved pastures below the canopy. The general concensus among planters is that goats are superior weeders than cattle but are much more difficult to manage.

Goats generally run unfenced and are semiferal, being harvested sporadically for shipment to market. Some of the larger planters, however, have upgraded their goat operations by including fencing, night housing, drenching, and pasture improvement in their management programs. Yields from improved pastures under coconuts in Fiji are presented in Table 3.

Caribbean pine

There is very little integration with livestock in the 50,000 ha of pine plantations in Fiji, despite promising initial research (Partridge et al. 1977; Bell 1981). Recent large-scale experiments have shown that returns from cattle grazing under pine do not cover operating costs; cattle do, however, remove excess fuel from the plantations, thereby reducing fire risk (Drysdale 1982). Goats are known to damage pine trees by debarking. In addition to this, control of goats grazed extensively at low stocking densities under pine is likely to be difficult. For these reasons, it is unlikely that widespread integration of goats or sheep with Caribbean pine is practicable.

Cocoa

The 3550 ha of cocoa plantations in Fiji are not integrated with livestock at all because of the palatability of cocoa leaves and bark. There is no utilization of cocoa pods

Table 3. Improved pasture yields under coconuts in Fiji.

Grass	Annual yield (dry) under young plantation[a] (t/ha)	Annual yield (dry) under 40-year-old plantation[b] (t/ha)
Paspalum plicatulum	7.9	9.5
Panicum maximum	6.7	3.8
Brachiaria humidicola	5.5	5.6
Dicanthium caricosum	3.1	6.7
Ischaemum indicum	2.5	7.5

[a] Source: Ranacou et al. (1973).
[b] Source: Parker et al. (1975).

for livestock feed because of the small-scale nature of the industry at present and the problems of drying pods in the high-rainfall cocoa areas.

Agroindustrial By-products in Small Ruminant Feeding

Supplementary feeding of the 4000 small ruminants on government farms is a well-established practice, as it is on many of the larger commercial farms. The main supplement used is a 1:1 mixture of coconut meal and wheat bran or rice pollard. Trials using these concentrates for varying amounts as supplementation for weaned male goats have yielded growth rates of 147 g/day (Hussain et al. 1981) and 89 g/day (Walkden-Brown et al. 1984) for goats penned indoors. Grazing goats supplemented with concentrates have yielded growth rates of 85 and 63 g/day (Walkden-Brown et al. 1984) and 129 g/day (Walkden-Brown et al. 1985).

Although Table 4 demonstrates that significant amounts of agricultural by-products suitable for ruminant feeding are produced in Fiji, only molasses is exported in large volumes, suggesting that most of the other by-products are being

Table 4. Production of agricultural by-products potentially useful as ruminant feed in Fiji.

By-product	Production, 1984 (t)	Effective local utilization[a] (%)
Coconut meal	8109	100
Wheat bran	10000	99
Rice pollard	2088	100
Molasses	188475	18
Bagasse	514800	95
Meat meal	337	100

[a] Sources: Coconut meal, Coconut Board of Fiji; wheat bran, Flour Mills of Fiji; rice pollard, estimate of 20% paddy production; molasses, Anon. (1985a); bagasse, Fiji Sugar Corporation; meat meal, Fiji Meat Industry Board.

consumed locally. In the case of bagasse, virtually all of the local production is used to fuel the sugar mills.

CRITICAL LIMITATIONS TO INCREASED SMALL RUMINANT PRODUCTIVITY

The critical limitations to productivity differ somewhat between the smallholder and the commercial production systems. Nevertheless, taking an overview, the major constraints to increased productivity in Fiji are predation by dogs, theft, disease (especially helminthosis), poor nutrition, land availability, the low skill level among farmers, the complex marketing system, and goat-induced environmental damage.

Technical Problems of Production

There are a large number of technical obstacles to efficient goat production in both the smallholder and commercial production systems. Here we describe five of these problems.

Theft and predation
Because of the relatively small size of goats, they are extremely susceptible to both theft and predation by dogs. The former is exacerbated by the high value of goats. Neither of these problems is likely to be eliminated. The response on the majority of farms has been to house goats at night; however, this greatly increases the capital and running costs of commercial goat farming.

Disease
Helminthosis is the major cause of reduced productivity in Fiji goats, particularly under intensive grazing situations. This problem is dealt with in detail further on in the paper.

Nutrition
Under most conditions in Fiji, suboptimal nutrition coupled with clinical or subclinical worm infection results in low overall productivity.

The majority of goats under the smallholder system graze a wide variety of grasses and broad-leaved plants on flat or undulating land of moderately good fertility. Diets may be supplemented with cut grasses and browse, but supplementary concentrates are rarely used. Nutrition under this system is usually limited by the availability of uncropped land, the length of the tether used, and the time allowed for grazing.

In contrast, most commercial goat operations are found on fairly steep hill country, on dark nigrescent soils, or on red humic latosols. Both of these soil types are grossly deficient in nitrogen and phosphorus and the humic latosols are also deficient in potassium.

In the dry and intermediate zones, approximately 50% of annual pasture growth occurs from February through April, with only 17% of annual growth occurring from June through October (S. Chand, personal communication). This marked lack of feed supply during the dry season is a serious barrier to improved productivity. An estimated 60-70% of does kid during this period and, as a result, suffer serious loss of condition and do not recommence cycling until the ensuing wet season.

In summary, the major nutritional constraints to improved small ruminant productivity are

- The low nutritional status of the grass-dominated swards on the steep hill country used for goats;
- The acute shortage of nutrients available during the May-November dry season, during which the bulk of kidding and lactation occurs (the two most physiologically demanding activities in the doe reproduction cycle); and
- The present inability to fully exploit the range of agricultural wastes and by-products available for both fully intensive goat production and the strategic supplementation of grazing goats.

Monofunctionality

Both goats and sheep in Fiji are kept exclusively for meat production. The productivity of goats in Fiji could be increased if milk or fibre were successfully introduced as an alternative product.

Stock control

Stock control by tethering can limit both the dry matter intake of the stock and the possible scale of operations. Fencing is extremely expensive, can exacerbate erosion, and, under prevailing methods of husbandry, often leads to extreme helminthosis. Where stock run uncontrolled, predation and theft often occur.

Environmental impact

A critical look at goat-farming systems in Fiji reveals that wherever goats are intensively grazed on hill country, erosion occurs. Contrary to the conventional view, experience in Fiji indicates that the more attempts to bring goats under control by fencing, the greater the erosion. This is because fenced areas are usually overstocked, this being the owner's way of attempting to recoup the considerable expense of goat fencing. The productivity of land severely degraded by goats appears to be reduced and the adverse publicity generated can threaten further development.

Sociopolitical Problems of Production

Land availability

For many smallholders, the size of their holding is a major constraint on total production. While there is no shortage of land available for goat farming in Fiji, approximately 82% of all land is communally owned by native Fijians and cannot be freely traded (Anon. 1980). A large number of communal goat-farming projects have been attempted in Fiji, most of which have failed. It is apparent that individual ownership is a key to successful goat farming. It is becoming increasingly difficult, however, for individuals of all races, including native Fijians, to obtain individual leases on blocks of land of a size suitable for commercial goat farming.

Farmer's husbandry skill

The skills and prerequisites required for successful goat farming are fairly well defined. Despite the efforts of government extension workers, these skills have, so far, only been adopted by the larger commercial farmers and do not appear to have percolated through to the whole farming community. This situation is improving, however.

Marketing

Approximately 98% of goats are marketed on the hoof direct to consumers or middlemen. Demand is strongly seasonal and subject to fluctuation. At present, there are no live-goat markets in urban areas. Goats marketed through the abattoir-butchery network realized very much lower returns than those marketed live. The present marketing system is erratic, time consuming for the large producer, and places limits on both the location of goat farms and the scale of operations that can be undertaken.

PROSPECTS FOR INCREASED PRODUCTIVITY

Potential Innovations in Smallholder Production Systems

Increases in productivity in the smallholder sector could best be realized by improved helminth control, more rapid introduction of improved breeding bucks, and increased use of supplementation during the dry season. The current Australian Centre for International Agricultural Research (ACIAR) supported project on helminthosis should provide valuable data that will quantify the extent of the helminthosis problem in tethered goats and enable sound helminth prevention or control programs to be recommended to smallholders, if necessary.

Goats on many smallholder farms are severely inbred because of the practice of breeding their own replacement bucks. Selected local goats on government stations have been crossbred with imported milch and dual-purpose breeds and objectively selected for growth and fertility characteristics since 1950. Up to 300 selected breeding bucks per annum from these stations are available for purchase by farmers at reasonable rates. The experience on commercial farms is that these animals have a substantial positive effect on productivity. While significant increases in productivity could be achieved by the genetic improvement of smallholder stock, it is unlikely that this can occur at a rate much beyond the present rate without a massive publicity program, backed up with hard research data and an increased availability of improved bucks. There is a definite need to accurately quantify the benefits that arise from the use of improved bloodlines.

At present, very little supplementation occurs in goats maintained under smallholder systems. However, although there is a critical grass shortage during the months from May through November, many of the locally prominent trees carry valuable, edible forage that could be utilized as fodder (e.g., Glyricidia maculata, Leucaena leucocephala, Tamaridus indica, Mangifera indica, Psidium guajava, Samanea saman). Careful exploitation of this resource could result in increased productivity under smallholder conditions. In addition to this, research on government stations has shown that strategic supplementation with locally available concentrates (e.g., coconut meal, wheat, and rice brans) is very cost effective. There is scope for smallholders with good access to sources of supplementary feed and markets to successfully finish stock for market using intensive feeding methods.

It must be emphasized that, at present, research and extension is applied to solving the problems of larger scale commercial producers rather than those of smallholders. Therefore, innovative change in the smallholder production system is likely to be a slow process resulting from changes in commercial production.

Potential Innovations in Commercial Production Systems

At present, substantial increases in productivity are being obtained by vigorous advocation of three basic husbandry practices:

- Drenching all stock every 3 weeks with a high dosage of broad-spectrum anthelmintic wherever the stocking density exceeds 2.5 breeding does/ha;
- Maintaining kids indoors for the first 2-3 months of life, giving them free access to fresh water and green feed during the day and mothering at night; and
- Using forms of stock control other than fencing wherever possible.

However, the following five changes are perhaps the key to dramatically increased productivity of Fiji's commercial goat farms:

- Controlling helminthosis (the ACIAR project should make a major contribution in this area);
- Improving the nutritional base by, first, identifying and using pasture species with good seed-production characteristics that give improved dry season yields; second, widespread adoption of growing dry season "fodder reserves" in close proximity to night yards, using such fodders as elephant grass and Leucaena; third, more extensive use of locally produced concentrates in goat feeding (there is a need for firm guidelines to be given to farmers regarding optimum levels of supplementation); and, fourth, pasture fertilization with high input - high output grazing systems.
- Increasing the level of integration of goats with coconuts.

- Ultimately developing a viable system of raising goats totally indoors utilizing treated crop roughages (rice straw, sugarcane tops, bagasse) and local energy and protein concentrates. Under this system, worms, theft, dog attack, mismothering, stock segregation and environmental damage problems are all virtually eliminated. Sheep could then infiltrate the improved grazing land.

- Taking steps to determine the feasibility of introducing cashmere as an alternative product in Fiji. The seasonality of cashmere production and Fiji's relatively mild climate offer some hope that this could prove successful.

A variable amount of research activity is occurring in all of the above areas except the last, which is about to be attempted by an entrepreneur. The prospect for progress in these areas is quite good.

Nevertheless, future productivity of grazing systems will always be limited by the need to yard stock at night to prevent theft and predation. Should a method be devised to allow stock to graze unfettered night and day, further increases in productivity could be expected.

DISEASE AS A MAJOR CONSTRAINT

Small ruminants in Fiji suffer from a number of diseases (Table 5), many of which are also found in other parts of Oceania and Southeast Asia. One health problem stands out above all others. Internal parasitism has been identified as a serious impediment to the development of small ruminant industries not only in Fiji, but also in many other parts of the wet tropics (Sellers 1979; Hussain, Naidu et al. 1983; Hussain, Walkden-Brown et al. 1983; Clarkson 1985; Copland 1985; Hussain 1985; Walkden-Brown 1984, 1985).

The Problem

The importance of intestinal nematodes in Fiji was recognized earlier this century (Chapple 1921; Turbet 1929); however, in recent years, their effects have become more pronounced as the population increases and production methods intensify. Today, intestinal nematodes are considered to be one of the greatest constraints on future development of the

Table 5. Diseases of goats and sheep in Fiji.

Disease	Synonym(s)	Frequency of diagnosis[a]
Caprine arthritis and encephalitis virus	Caprine retrovirus, viral leucoencephalitis	+
Orf	Scabby mouth, contagious pustular, dermatitis	-
Caprine herpes virus		-
Q fever	Nine-mile fever	-
Tetanus	Lockjaw	++
Mastitis	Udder infection	+++
Benign foot rot		+++
Melioidosis		-
Dermatiphilosis	Streptothricosis, lumpy wool	+++
Pasteurellosis	*Pasteurella* pneumonia	+
Gastrointestinal nematodes	Intestinal worms	+++
Lungworms		+
Tapeworms		+
Mange	Psoroptic mange, sarcoptic mange	+
Lice	*Linognathus stenopsis* infestation	+++
Coccidiosis		+++
Cerebrocortical necrosis	Polyencephalomalacia, CCN	+
Pregnancy toxemia		+
Urinary calculi	Bladder stones	++
Plant poisoning	Toxicosis	+
Ear and vulva tumours	Skin cancer	+

[a] -, Rare; +, occasional; ++, common; +++, very common.

small ruminant industry (Hussain, Walkden-Brown et al. 1983; Hussain 1985; Walkden-Brown 1985).

It is difficult to quantify the effects of internal parasites in small ruminants, particularly when many losses go undocumented. However, there are numerous reports describing mortality rates of up to 100% in growing goats and 30-50% in adult stock (Clarkson 1985). Even on well-managed government research stations, breakdowns in worm control have resulted in mortality rates of over 20% in goat herds (Anon. 1984a).

In addition, although mortality rates are excessive, the less dramatic but widely distributed losses in production caused by internal parasites in small ruminants may well have an even greater economic impact than deaths. Unfortunately, although the effects of internal parasites on production are moderately well known for sheep in temperate and subtropical cimates, there appears to be a paucity of quantitative information relating to goats and sheep in the humid tropics (Sellers 1979). Nevertheless, suboptimal growth rates and low fertility in goats are frequently attributed to heavy worm infestations in Fiji (Clarkson 1985), with dramatic improvements being seen when effective worm control is introduced. For example, the weaning percentage rose by over 20% on one government goat station following the use of an effective drenching program. This was accompanied by a 69% reduction in mortality (Anon. 1985a).

The Parasites

Several species of nematode parasite are found in Fijian goats and sheep (Table 6), but Haemonchus contortus and Trichostrongylus colubriformis appear to be responsible for most of the pathological effects although the role of Strongyloides papillosus may have been underestimated in the past. The way in which these worms cause disease is complex (Symons and Steel 1978): anemia, diarrhea, reduced appetite, catabolism of plasma proteins, reduced digestion, absorption of food, and host immune responses all contribute in varying degrees to what is generally termed a protein-losing enteropathy.

The Present Remedy

After extensive field experience, the Government of Fiji now recommends that goats and sheep on commercial farms be drenched every 3 weeks to prevent deaths and loss of production as a result of gastrointestinal parasites. This represents

Table 6. Gastrointestinal parasites of Fijian goats and sheep.

Parasite	Site	Frequency of observation[a]
Haemonchus contortus	Abomasum	+++
H. placei	Abomasum	!
H. similis	Abomasum	!
Mecistocirrus digitatus	Abomasum	!
Trichostrongylus axei	Abomasum	+++
T. colubriformis	Small intestine	+++
Strongyloides papillosus	Small intestine	+++
Moniezia expansa	Small intestine	+++
Oesophagostomum columbianum	Large intestine	++
Trichuris spp.	Large intestine	+

[a] +, occasional; ++, common; +++, very common; !, present in cattle and potentially infectious to goats and sheep but not yet identified in these species.

16 drenches each year. The challenge is so high in the wetter areas that detrimental effects become apparent if even one of these drenches is missed.

Although effectively controlling parasites, this suppressive regime has resulted in two undesirable sequelae. First, the cost of anthelmintics has become a major factor in the economics of production. A recent study on the Makogai sheep project indicates that the purchase of anthelmintics represents a high proportion of variable farm costs (Anon. 1986b). Second, the high frequency of drenching appears to be rapidly selecting for anthelmintic resistance. Combined levamisole and benzimidozole resistance has been confirmed on several commercial and government farms (D.J.D. Banks, unpublished data) and the only effective anthelmintic currently available in Fiji for use on these properties is ivomectin. Examination of farm records suggests that resistance is developing at a rate that exceeds the introduction of new anthelmintics and, if the present trend continues, it is reasonable to expect the appearance of ivomectin resistance within the next 3 or 4 years.

RESEARCH

With this background, it became evident that a system of worm control was required that did not rely entirely on the suppressive use of drugs. Previous attempts at hand-feeding goats indoors on slatted floors have been of dubious economic viability (Hussain, Walkden-Brown et al. 1983), with the result that the industry is still based largely on free-grazing systems.

Before any control strategies could be attempted in the wet tropical environment of the Pacific Islands, a number of questions needed to be answered:

- What is the seasonal pattern of egg hatching and larval survival on pasture in the wetter and drier zones in the Pacific?
- What is the seasonal pattern of larval intake and population dynamics in grazing small ruminants of different physiological status (e.g., growers, lactating, and dry)?
- What is the heritability of parasitic resistance in small ruminant populations of the Pacific and is a breeding program for host resistance feasible?
- What is the prevalence and distribution of anthelmintic resistance related to various types of management?

In early 1986, a research program began that was designed to answer these questions. Funded by the ACIAR and executed jointly by staff from the Fijian Ministry of Primary Industries and the Division of Animal Health, Commonwealth Scientific and Industrial Research Organization (Australia), the program's headquarters are in Fiji, with small collaborative centres in Western Samoa, Tonga, Vanuatu, and the Solomon Islands. The work of the collaborative centres is to collect information to determine whether control strategies formulated in Fiji will be applicable to other countries of the Pacific Islands.

The sequence of the program is

- To examine the epidemiological and host genetic factors influencing helminthosis in small ruminant populations;
- To verify and determine the extent of anthelmintic resistance;

- To construct a computer simulation model to aid in the design of management strategies aimed at parasite control with minimal use of anthelmintics and to predict periods of high risk;
- To test potential management strategies in the field; and
- To report the results of these investigations to national livestock officers.

The program is still in the early stages and no results are available. However, management strategies that will be examined include rotational grazing, periodic zero grazing, use of tall species of grass and legumes, sustained anthelmintic intake (e.g., slow-release boluses), resistant small ruminant genotypes, the use of narrow-spectrum drugs, and strategic drenching. The project is an example of the role of animal health research within the broader systems approach to crop and livestock production.

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DISCUSSION

In Malaysia, the Guthrie Research Chemara has instituted a large-scale research and development program involving more than 1000 ewes and 1500 lambs. Ewes purchased from villages have been put on a 3-6 month adaptation and crossed with Pale Dorset and Wiltshire Horn rams.

Crossbreeding results to date have shown that the F_1 crossbreds have been greatly superior to the local breed in growth rate and in reduced lamb mortality. Responses to supplementary feeding of weaned lambs have been recorded. High energy supplementation has shown that 12-15 kg carcass weight lambs can be produced in 6-8 months and such carcasses are very lean. A major advantage of the sheep system is that weeding costs are reduced to about half of the normal cost.

The major constraints are availability of animals and feeds, and disease and breeding selection. It is concluded, however, that the outlook is promising and that the system has the potential to complement tree crop production.

Discussion pointed out that there had not yet been an opportunity to test, for example, hairless breeds for crossing, nor had there yet been an opportunity to improve performance through culling selection. The plantation industry was closely watching the progress of the experiment.

Small ruminant production systems in Indonesia include full confinement, confinement and grazing, and grazing. As far as integration with tree crops is concerned, this is mostly done in smallholdings occupying 80-90% of the area. The undergrowth in the plantations is dominated by the grass Imperata cylindrica.

Studies in North Sumatra have shown that the grazing of sheep in plantations does not reduce tree production. Grasses such as Paspalum and some broadleaf species such as Mikania are eaten but ferns and the legume Calapogonium are not palatable. Supplementary feeding trials have given improved sheep performance, but this is economic only at the higher levels of supplementation.

The major feed constraints are the variability of herbage production, abundant in the wet but insufficient in the dry season, and feed quality. High fibre content, nutrient imbalance, and palatability reduce the quality.

It was suggested that food crops be introduced in the first 3 years to provide food and early income and thereafter to introduce sheep. Integration of sheep with tree crops and especially rubber is promising, but some supplementation may be necessary.

Discussion pointed out that some planters have objections to including food and forage crops under rubber, but that research is necessary to demonstrate that these do not reduce tree crop production. The North Sumatra study is focusing on using natural indigenous pasture growth plus supplementation rather than planting forages.

In the Philippines, coconut plantations dominate primarily in smallholdings of less than 5 ha, and more than 90% of the goats are kept here. There has been a very rapid expansion of the goat population. Their numbers have tripled from 780,000 in 1976 to 2,300,000 in 1984, but there are only 30,000 sheep in the area. There are three main systems: traditional, with native herbage; coconut-crop, involving corn, bananas, sugarcane; and multistory crops.

The integration of small ruminants into coconut plantations has given increased yields of copra, although this has been rather variable. Increases were recorded under Setaria and Centrosema but not under Brachiaria. Recommendations are to improve a small area in cultivated pastures. This would increase considerably the carrying capacity of the plantation. The depressed prices for copra are causing a decrease in coconut area and this together with the increase in goat numbers provides a good chance for the successful integration of goats into tree cropping. In terms of the species planted, Brachiaria decumbens and Centrosema are the most shade tolerant.

The main purpose of goats is to provide meat; very few are used for milk. The carrying capacity of 25-50 animals/ha was questioned. The clarification given was that the value was calculated from the dry matter yield and feed requirements.

Animal diseases in Indonesia can be divided into three groups:

- Those known to be of economic significance, of which parasitic diseases, especially gastrointestinal nematodiasis and fascioliasis, are the most important;
- Those of unknown economic importance; and
- Those in which small ruminants play an important epidemiological role, e.g., foot and mouth disease (FMD) and malignant catarrhal fever (MCF) of Bali cattle and buffalo.

Pneumonia, for example, was important in both sheep and goats, but no studies have been made.

The causes of lamb mortality were not known, e.g., whether management, nutrition, or disease was the main factor. It was also difficult to get carcasses for inspection and disease diagnosis. Sarcoptic mange in goats was a killer disease in kids and chemotherapeutic control was difficult. The available drugs killed adult flukes (Fasciola) but not the immature forms, so an effective drug to be administered at the immature stage is needed.

SR-CRSP has set up studies on parasitic diseases and some experiments have shown good responses in live weight gain and reduced mortality. Generally, a single drenching is ineffective because there is rapid reinfestation. It appears that repeated, broad-spectrum drenchings are necessary.

The problem of diseases of unknown economic importance opened up a vast, unclear area. Small ruminants, however, can play an important role in the control of the spread of FMD and MCF in Indonesia, e.g., Bali cattle and sheep cannot coexist.

The paper and discussion on diseases highlighted our ignorance of the epidemiology of disease in Indonesia. The author stressed that disease control must be related to management. It must also be accepted that disease control may not be economically feasible.

Many questions were asked on this subject. From these, the following points arose. There are breed differences in resistance to haemonchosis. Experience in New Guinea has shown that there are very wide breed differences in susceptibility to some worms, but one can never completely eliminate gastrointestinal parasites. The two small ruminant species, sheep and goats, differ in susceptibility to internal parasitism because of the faster clearance rates of drugs in goats. Single treatments of anthelmintics are largely ineffective.

Fiji is a small country made up of several islands. There is a strong demand for goat meat because of the large-scale sector of the population that is of Indian origin. There are 183,000 goats but only 2,000 sheep.

The goat production system is an all-grazing system with no zero grazing and very little supplementation. Smallholders each own a small number of goats, but commercial herds of 50-1500 animals are important. Within this commercial sector, the most important system is the semi-intensive one where the goats are yarded at night. In the daytime, they are grazed within fenced areas. They are integrated with cropping, mostly with sugarcane. Intensive, zero grazing with supplements has been entirely unsuccessful. Few goats are grazed under tree crops. Cattle are preferred because although goats are better breeders, they are more difficult to control.

Most agroindustrial by-products are used by cattle, poultry, and pigs, so the feed supply for goats is largely derived from grazing. Among the limitations are

- Theft and predation by dogs (many dogs are kept in the villages);
- Suboptimal nutrition, especially during the long dry period;
- Erosion on hillsides; and
- Management; control is a problem: tethering limits of 1-20 animals and both herding and fencing are expensive.

Prospects are mostly in the commercial sector:

- Present recommendations are to repeat drenching every 3 weeks;
- Kids are kept indoors for the first 3 months;
- Grazing cultivated pastures on small areas for strategic purposes;

- Increasing the use of supplements; and
- Changing the type of goat from total meat goats to the cashmere type.

Disease is a major constraint, especially haemonchosis. This has led to the development of a major research program with the assistance of ACIAR.

The question was raised as to why pasture control was not used as an adjunct to drenching. It was stated that responses from rotational grazing have, in the past, been disappointing, although advisors are now recommending that it should be adopted. Also, it was explained that the intensive system was a failure because of low-quality agricultural crop residues such as cane tops were used and the digestibility and intake were too low. It was questioned whether crossbreeding had been adopted. In response, it was stated that local goats crossed with Anglo Nubian crossbreds were superior, provided the level of Anglo Nubian blood was kept at 50% and did not exceed this level.

Session III

Strategies and Research Methodology

BREEDING STRATEGIES FOR SMALL RUMINANTS IN INTEGRATED CROP-LIVESTOCK PRODUCTION SYSTEMS

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Abstract *This paper stresses the importance of genetic potential and of breeding and management level in determining animal performance, and the importance of an appropriate match of these two factors for efficient animal production. A feature of crop-livestock production systems, as contrasted with strictly pastoral systems, is the availability of crop residues and by-products for supplementation during times of limited forage availability, making possible the effective utilization of genotypes with higher potential for reproduction, growth, and lactation. General performance traits of some breeds of sheep and goats in South and Southeast Asia are reviewed; the importance of adaptability in terms of net reproductive rate and viability of locally adapted stocks is emphasized. Breeding strategies suggested as being most applicable to the smallholder production systems under consideration are selection within local stocks, including intense initial screening for desired performance traits, and development of new stocks based on crosses between improved breeds and well-adapted, local breeds. The latter strategy may be particularly useful where milk production is a goal. Direct replacement of local breeds by imported, improved breeds or grading up to an improved breed may result in an unacceptable loss of adaptability. Repeat production of* F_1*'s or systematic crossing systems to exploit heterosis may lead to the highest levels of performance per animal, but may not be feasible in smallholder production systems. Methods of disseminating genetic improvement in such systems are suggested.*

The main feature of crop-livestock production systems is that they provide harvested feed, crop by-products, and residues that may be used as supplements to seasonal forage production to meet the nutrient needs of the livestock. This is a possibility not available or economically feasible for many pastoral producers and is often the only means of compensating for the low-quality forages of the humid tropics. The potential for supplementary feeding means that it may be possible to use animals with higher genetic merit for such important traits as reproduction, lactation, and growth to good advantage. Supplementary feeding can contribute to reduced pre- and postweaning mortality as well as to increased reproduction and growth rates. Of particular significance to small ruminant production systems is that supplementary feeding may permit exploitation of the shorter reproductive cycle of these animals: producing lamb or kid crops at 8-9 month intervals. This can lead to substantial increases in total productivity compared with the typical intervals of 1 year or more, which are dictated in pastoral systems by feed supply and in large ruminants by their gestation period. It is an avenue for improvement of small ruminant production that merits much more attention, from both genetic and management aspects, than it has received.

GENERAL STRATEGY

Livestock performance levels depend on the genetic potential of the animals and on nutrition, disease control, and management practices adequate to permit expression of this potential.

In considering the means of improving livestock performance and productivity in developing countries, two errors are sometimes made. The first of these is to assume that relatively low levels of performance, such as slow growth rates, are due to inferior genetic potential, and to import breeds with higher levels of performance in the environment where they have developed. For example, growth rates of sheep and goats in tropical countries are typically 100 g/day, while specialized meat breeds in temperate countries may achieve average growth rates of at least 300 g/day. Importation of temperate breeds into a tropical country is done in the expectation of doubling or tripling growth rates by breed replacement or grading up. Unfortunately, increases of this order are rarely realized. The imported breeds grow much more slowly in the tropical climate mainly because of the typically lower quality of tropical forages as well as disease and climatic stresses. Also, the local animals, if fed the levels of supplements necessary to obtain satisfactory growth rates of the imported breeds, often perform much better than expected. An even more important consideration is that reproduction rates of the imported animals tend to be low. For example, Patterson (1983) reported drastically lower fertility of imported Suffolk and Dorset sheep as compared with the local Blackbelly breed in Barbados (14°N). Data from interbreed matings in that study showed that imported rams and ewes both had impaired fertility compared with the local breeds. A second error, also with serious implications, is to assume that the relatively low performance levels of tropical livestock are due entirely to environmental constraints. This view holds that the genetic resources are present locally but simply need to be exploited by removing nutritional, disease, or management constraints.

The importance of specific knowledge about the genetic potential of the animals used can be illustrated with an example from Indonesian sheep. Javanese sheep (Priangan, Thin Tail, Garut) have been reported by a number of authors (e.g., Mason 1980) to be highly prolific, suggesting the potential of this type of animal for high productivity under good management. Mean litter sizes range from 1.4 to 1.9, i.e., moderately high but not exceptional. Examination of individual ewe records, however, reveal two kinds of ewes: those that never have more than two lambs and exceptional individuals that usually have three or more lambs (Bradford et al. 1986). Repeatability and heritability of ovulation rate and litter size were found to be very high, and daughters segregated into the two classes in a very striking fashion (Table 1). The data in Table 2 strongly suggest the presence of a gene that has a large effect on ovulation rate and litter size, similar to the Booroola gene (Bindon and Piper 1982). The occurrence of exceptionally prolific ewes in two other groups of Indonesian sheep, the Javanese Fat Tail and the Semerang, supports this hypothesis. If this hypothesis holds, it suggests a means of producing, relatively quickly, strains with mean litter sizes of 1.3-1.5 or above 2.5. Knowing that ewes can be expected to perform consistently in one or the other of these ways provides a means of much more efficient production of the sheep than the current situation, where the producer does not know until after one or more lambings whether a ewe has the potential to provide a return that will justify a high level of feed and management. A second example of the importance of specific genetic knowledge is the lower performance in the tropics of woolled sheep compared with that of hair sheep or of animals with less wool cover (Odenya 1982; Inounu and Sitorus 1984). The elimination of wool by selection or avoiding the problem by not

Table 1. Segregation of litter size in Javanese sheep.

	High dams (1 or more records≥3)			Low dams (all records = 1 or 2)		
	No.	No. records	X̄	No.	No. records	X̄
Dams[a]	23	74	2.74	37	103	1.48
All daughters	39	95	1.85	42	86	1.38
High daughters[b]	18	48	2.31	2	6	2.83
Low daughters[b]	21	47	1.38	40	80	1.28

Source: Bradford et al. (1986).

[a] Counting each dam only once, regardless of number of daughters.

[b] Classified on the same basis as high and low dams.

crossing hair sheep with imported woolled breeds are, therefore, potential means of achieving higher performance.

We suggest that to improve livestock performance and productivity, it must be recognized that all phenotypes are a function of both genotype and environment and that output/input, i.e., efficiency, will be maximized by an appropriate matching of genetic potential with level of feeding and management. Such matching requires consideration of all the important components of performance, especially reproduction and viability. For this reason, locally adapted genotypes should always be the reference point in any evaluation of stocks for improvement.

SMALL RUMINANT BREED RESOURCES OF SOUTH AND SOUTHEAST ASIA

Certain indigenous breeds are reported to be better adapted to harsher conditions and to lower than average feed and management levels. These breeds tend to be characterized by small size and, usually, low prolificacy. They include, for sheep, the indigenous Malaysian (Devendra 1975), the Jaffna from Sri Lanka (Buvanendran 1978; Goonewardene et al. 1981; Ravindran et al. 1983; Goonewardene et al. 1984), and an indigenous Thai breed (Falvey 1979). Goat breeds in this category

Table 2. Fertility of local (Barbados Blackbelly) and imported (Suffolk and Dorset) rams and ewes in a tropical environment.

Breed of ram	Breed of ewe					
	Blackbelly		Suffolk		Dorset	
	No.	% lambed	No.	% lambed	No.	% lambed
Blackbelly	299	78.3	15	63.3	-	-
Suffolk	76	47.4	52	25.0	-	-
Dorset	162	51.8	-	-	53	5.7

Source: Patterson (1983).

include indigenous stocks of Malaysia, Thailand, and Indonesia, commonly called Kambing Kacang (Katjan) (Gall 1981; Devendra and McElroy 1982).

Where feeding and management will support animals with higher prolificacy potential, the Javanese Thin Tail and Fat Tail (Mason 1978, 1980; Obst et al. 1980; Bradford et al. 1986) and the Chinese Hu breed (Cheng 1984a, b) may be suitable sheep breeds. Among goats, the Bengal (Acharya 1982), Leizhou (Cheng 1984b), and Barbari (Sahni and Roy 1967; Gall 1981; Acharya 1982) show above-average prolificacy.

Breeds with larger mature size and higher growth potential include, for sheep, the Javanese Fat Tail (Mason 1978, 1980; George 1982), the Nellore (Littlewood 1936; Acharya 1982), and Red Madras and Ganjam (Acharya 1982), and, for goats, the Jamnapari and Ganjam of India (Gall 1981; Acharya 1982), the Etawah of Indonesia (Devendra and McElroy 1982), and Matou and Leizhou of China (Cheng 1984b). The Jamnapari (from which the Etawah is almost certainly derived) is also above average in milk-production potential.

THE PLACE OF IMPROVED GENOTYPES

An improved genotype usually refers to a population that has been selected for performance traits and, thus, has a higher potential than an unselected breed for one or more components of performance. Many improved breeds are from temperate climates, where improvement programs have been in place longer than in the tropics. Crossbred animals produced by mating breeds with unselected, local stocks may also be classified as improved genotypes. In addition, animals carrying specific genes for high production potential, such as the Booroola gene, would also be classified as improved, regardless of the source of the gene.

Deciding on the best genotype for a particular production system is an important step. In general, one wants the highest prolificacy, growth rate, or milk yield compatible with satisfactory adaptation to the environment. Adaptability is determined primarily by fertility and by viability of young and of adults. While there are no absolute rules, the following are suggested indicators of lack of adaptation:

- Fertility from a 2-month mating season either less than 80% or more than 10% below that of adapted local stocks;
- Mortality of lambs or kids from birth to weaning exceeding 20% of all young born (a frequent contributor to high mortality is multiple births; in an environment in which mortality of single, twin, and triplet (or more) young is 12, 25, and 60%, respectively, a stock with a significant (e.g., $\geq$10%) incidence of triplets is not adapted);
- Lambing or kidding intervals exceeding 12 months;
- Growth rates or milk yields of introduced breeds less than 50% those typical of these breeds in their home environment; and
- Annual mortality of animals aged 1-6 years exceeding 5%.

For effective exploitation of improved genotypes, feeding, management, and disease control should be sufficient to permit animals to equal or preferably exceed these standards. A larger mature size of an improved breed will rarely compensate for a lower fertility of that breed compared with a (usually smaller) locally adapted breed. Illustrations of this point are given by Fletcher et al. (1982) and Alderson et al. (1983). If feeding and management are sufficient for good viability of young born as multiples and for good growth rates and milk production, however, resources will be wasted if the animals used do not have the genetic potential for these levels of performance. This is often a particularly important issue for milk production; the difference between improved dairy breeds and most indigenous breeds of sheep and goats in milk production potential is sufficient that milking is often not justified for animals that do not carry some improved dairy breed inheritance.

BREEDING STRATEGIES

Strategies for improving the genetic potential of animals include

- Selection within local breeds and types;
- Breed replacement (partial or complete); and
- Systematic crossbreeding.

The amount and kind of effort required for success and the time scale for response differ considerably among these three strategies.

Selection Within Local Stocks

This strategy is indicated where adaptability is particularly important, which is often the case where tropical diseases and parasites result in an extremely poor performance of imported temperate breeds. This approach avoids the often high cost of importation, the risk of introducing new diseases, and has the additional advantage of maintaining animals and products familiar to local producers and consumers. The principal disadvantage is a relatively slow rate of change: often an annual rate of only 1-2% for well-designed, well-executed selection programs. Program officers, whether representing local or international agencies, like to see rapid change and rapid return on investment. Unfortunately, the return on investment from inappropriate importation is likely to be negative.

An approach to utilizing locally adapted germ plasm, not yet widely used but of high potential, is screening local populations for superior animals. Some traits for which screening of large numbers of local populations could be very useful include

- Selection of wool-free animals from mixed wool-hair sheep populations where the fibre crop produced is not utilized;

- Selection of twin-producing ewes or does from populations where twinning rate is low and it is desired to increase it (it is important in this situation to select females raising twins);

- Selection of fibre-producing animals with the desired fibre diameter and density, and freedom from defects such as kemp, where fibre is an important source of income; and

- Selection on a combination of traits, e.g., large rams free of wool and with desired phenotype with regard to horns, colour, etc., and large females with the phenotypic criteria listed for rams and that are capable of rearing multiple young to good weights.

The cost of picking the best 100 animals out of a local population of 5,000-10,000 animals (best 1-2%) may be less than the cost of importing a new breed. Such selection could result in a one-step increase in productivity or profitability of 10-15%, while maintaining a well-adapted stock; the annual increases of 1-2% from continued selection can then be added.

Breed Replacement

A need for a substantial one-step increase in genetic potential, e.g., in milk-producing ability, to initiate a dairy production system, may justify the importation of improved germ plasm. The need to compare the new genotypes with local stocks in all aspects of performance, including fertility, parturition interval, and viability of both young and adults, cannot be overstressed.

Where feeding, management, and disease control can be improved sufficiently to permit the improved breed to express its full genetic potential, then complete breed replacement could be indicated; this is unlikely in most environments for small ruminants in Southeast Asia. A more common situation is that the F_1 or backcrosses involving the improved and local breeds are significantly superior to both of the local breeds. In this situation, repeat crossing or development of a new "synthetic" based on a crossbred foundation is indicated. The procedure is to establish by careful evaluation what level of improved breed inheritance gives the best performance in the management situation likely to hold in the future and to devise a strategy to maintain that level.

Systematic repeat-crossing programs are difficult to maintain under the best of conditions and often impossible to maintain in existing production environments in developed or developing countries. The system of choice may, therefore, be the development of a new breed based on the crossbred. Having decided on an optimum level of improved breed inheritance (e.g., 25, 50, 62.5%), animals carrying this percentage are intermated with selection toward defined performance goals. The principal disadvantage of this approach is that half (or more) of the heterosis realized in the F_1 may be lost and, thus, a substantial decline in performance may occur. However, if additive merit of the F_1 is much higher than that of the local breed for production traits and of the imported breed for adaptability, the synthetic may be the best genotype available. It may also be possible to reduce the loss in heterosis by use of more than two breeds in the synthetic. For example, two dairy breeds such as Anglo-Nubian and Alpine and two local breeds such as Etawah and Kacang might be used to produce a four-way cross to be used as the base for a new dual-purpose (milk and meat) goat breed. In theory, 75% of the F_1 heterosis should be retained in the synthetic. The difference in retained heterosis must be evaluated against the possible loss in additive merit from the use of more than the two best breeds.

Systematic Crossbreeding

Repeat crossing to produce F_1's between local and improved breeds requires maintenance of the pure local breed and either the pure imported breed or a source of semen as well as continuously following a specific mating plan.

Production of three- or four-way crosses adds more requirements. Two- or three-breed rotational crossing schemes require, at the least, a continued availability of purebred semen and a knowledge of the breed makeup of all females. If these steps can be followed, the benefits of heterosis may be substantial. These steps, however, may be quite out of the question in a village or pastoral system; for this reason, we do not feel these are practical breeding strategies in most situations for the species and production environments under consideration here. The use of a selected local breed or established synthetic, where all males and females are of the same population (or converging towards the same population), is usually much more feasible.

PROBLEMS OF USING IMPROVED GENOTYPES AT THE SMALL FARM LEVEL

There are two particular difficulties in effecting genetic improvement at the small farm level. First, small ruminants are used as a cash reserve and are often sold or purchased depending on whether the owner needs or has money. The resulting lack of continuity of animals within a flock makes performance recording, selection, or evaluation of a new genotype very difficult.

Second, many smallholders do not keep enough breeding females to justify keeping a breeding male, but are dependent on a neighbour's male(s), matings under common grazing conditions, etc. This makes such things as parentage recording or carrying out a specific mating plan difficult to impossible. The lack of regularly available males and the difficulties of estrus detection result in long intervals between parturitions (Bell et al. 1983). This has more serious implications for productivity of the flock than for genetic improvement, but also slows the rate of progress from selection or introduction of improved males.

PRACTICAL ASPECTS: OPTIONS FOR THE USE OF IMPROVED GENOTYPES AT THE SMALL FARM LEVEL

There are several ways of using improved genotypes at the small farm level. One option is the distribution to smallholders of males from a selected stock of the local breed (e.g., improved by intense screening and within flock selection), males of an imported breed, or imported x local males, depending on whether the desired smallholder animal carries 50 or 25% improved breed inheritance. The improved males will often come from a government-operated multiplication centre. There are two requirements for this approach to have a favourable impact: first, the males distributed should be clearly superior to the smallholder's own animals and, second, the producers must use the distributed males rather than their own. Distribution schemes sometimes fail on both counts, and if the distributed males are in fact not superior, the farmers may be exercising sound judgment in not using them.

A second option, which may be combined with the first, is for a group of village producers to organize cooperative use of males. Eight farmers with, say, a total of 30-40 females might select two superior males for use in their flocks. These males might come from a government research or multiplication station or might be selected from their own or a neighbouring village. Each farmer would run a male with his females 1 out of 4 months on a regular rotation. Assuming good fertility of females 60-90 days postpartum, all females should have lambing or kidding intervals of approximately 8 months. Parturition would occur during only 3 months of the year, facilitating management; all sires would be selected by the farmers and, hence, should meet their standards; sires of all animals would be known and males could be changed on a schedule to avoid inbreeding. Extension workers or village officers could assist with sire selection and could keep a record of all sire use, which could facilitate the exchange of males between groups of farmers.

Assuming estrus-detection techniques used by farmers are adequate, females can be bred to a male maintained by one farmer in the village, who would be paid a fee for this service. The males so used could be obtained from one of the sources described in the first two options, with the extension service, where operational, assisting with selection of males and possibly with coordination and monitoring of the program.

As can be seen, there are different ways of introducing animals of improved genetic potential into smallholder flocks. The important consideration is identification and use of males superior in performance traits for that production system. Artificial insemination is another method of introducing superior germ plasm; however, because of the costs and requirements for technical expertise and precise timing associated with artificial insemination, systems using natural service are more appropriate in most situations involving small ruminants.

POTENTIAL IMPACT OF GENETIC IMPROVEMENT

Increases in production from using animals of improved genetic potential can be substantial. F_1 dairy x local breed females may produce 50-100% more milk than the local breed (Garcia 1982); crossing with a prolific breed can increase numbers born by more than 50% and offtake rates by 25-50% (Dickerson 1977); Dorper ewes with little wool (cover score, 2) weaned lambs 17% heavier than fully woolled ewes in the same flock (coat score, 6) (Odenya 1982). These are only a few of many examples. The increases in productivity cited will normally require some improvement in feeding and management, but a much smaller increase than the increase in outputs, where the animals involved have good fertility and viability. Thus, efficiency is increased, often substantially. We emphasize again, however, the importance of matching genetic potential to level of feeding and management. A high genetic potential without commensurate inputs and a high level of feeding and management for animals lacking the ability to respond represent a waste of resources. Only when these two factors are appropriately matched can animals make the expected and needed contribution to human welfare.

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STRATEGIES OTHER THAN BREEDING FOR THE DEVELOPMENT OF SMALL RUMINANTS

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Abstract *This paper discusses strategies other than breeding that are important to the development and contribution of small ruminants. These include, for example, precise production objectives, choice of species, reproductive efficiency, feeding and nutrition, exploring the avenues of production, and the components of infrastructure, research, linkages, and training. The choice of species for a particular production system is determined by such factors as the availability and quality of feed resources, feeding behaviour, availability of animals, survivability, relative price of meats, market outlets, and biomass production. The principal strategy should aim at increasing per animal productivity through making maximum use of the available feeds and improved efficiency in feeding and nutrition, in which increased use of crop residues and agroindustrial by-products, dietary nitrogen sources, and strategic use of supplementary protein sources are especially important. Where possible, fodder production should be increased to sustain year-round feeding. Of the avenues of production, the highest priority should be directed to systems integrated with tree cropping, followed by intensive small feeding systems that can make more use of the large reservoir of fibrous feeds. The* 20.3×10^6 *ha presently under permanent tree crops is underutilized; it is estimated that this area can support an additional* 81×10^6 *goats or sheep. Attention is drawn to the urgent need to take advantage of the large market potential for goat meat and mutton in the Near East, commensurate with more intensive stall feeding systems of production. Possibilities of how further improvements can make a significant impact on correcting the widening gap between production and consumption of food supply from small ruminants are discussed.*

Two previous papers in this workshop have discussed the types of prevailing production systems in South and Southeast Asia, the constraints that currently exist (Devendra, this volume), and the breeding strategies that need to be pursued within these systems (Bradford et al., this volume).

To complement these papers, it is relevant to consider all other aspects of development that concern the future of goats and sheep. This paper will focus on those strategies other than breeding that are important to the development and contribution of both species. Such strategies have been previously discussed (Devendra 1980, 1985a).

In general, it is especially important in seeking a high efficiency in specific feeding systems and in productivity to maintain an appropriate species, to aim for a realistic potential level of production, to take advantage of the available dietary ingredients, and to identify the objectives clearly in terms of production and profitability. In this, it is particularly important to understand the abilities of each species, their feeding behaviour, their response within individual environments, and their potential productivity in the context of efficient utilization of the production resources.

PRODUCTION OBJECTIVES

It is essential to have clear production objectives. Without these, it is impossible to maximize productivity from both species as well as ensure complete utilization of goat and sheep genetic resources. It is also imperative to relate the production objectives to the available production resources, prevailing market demand, consumer preferences, and the marketing strategies that may be required to link up with the market outlets. The following considerations are pertinent (adapted from Turner 1972).

Characteristics of the Products

Meat

Throughout the Asian region, goat meat and mutton are in very high demand. The demand for both outweighs supplies and this is reflected in high prices, especially of goat meat, and increased imports of mutton from Australia and New Zealand.

Quantity - Total amount of lean meat in the carcass (measured by live weight before slaughter). Growth rate, in the case of lambs, is related to efficiency of production. Total number of animals available for slaughter is likely to be more important than amount of meat in each animal. Total weight of offspring weaned per year per female is important.

Quality - Quantity and distribution of fat (excess undesirable).

Milk
Quantity - Total yield, lactation, length, persistency, and number of lactations.

Quality - Milk composition (butter fat and nonfat solids).

Carpet wool
Quantity - Clean wool per head.

Quality - Average fibre diameter (coarse fibre desirable). Presence of a proportion of medullated fibres (hair). Absence (or a very small proportion) of kemp (shed fibres or ones with the medulla occupying 90% of the diameter). Staple length. Percentage of clean scoured yield.

CHOICE OF SPECIES

The choice of species and, indeed, breed within a species is determined by several factors. The following factors are relevant: availability and quality of feed resources, feeding behaviour, availability of animals, survivability, relative price of meats, market outlets for meats, and biomass production.

A consideration of the appropriate species is important in relation to the resources available, the environment, and the market demand for specific products. In general, intensive systems will be influenced by the availability and quality of forage and, in turn, the choice of species. With the more extensive systems, both species are often herded together; a higher proportion in these mixed herds is an indication of superior survivability by goats and of an ability to cope with feed shortages.

While the husbandry of goats and sheep is complementary, both species have some distinctive characteristics. It is important that these features are recognized in the choice of animals appropriate to individual production systems. Both species are often run together in traditional management systems; however, where there is a specific demand for products from one or the other species or when the prevailing situation favours a particular species, a single, appropriate species is chosen. Goats favour drier conditions and areas with abundant browse. Sheep, by virtue of their less inquisitive habits, are more suited to areas with more herbage for grazing.

Unlike the semi-arid and arid regions where many species (sheep, goats, and camels, but rarely cattle) are reared together in essentially nomadic and transhumant pastoralist systems, in humid tropical Asia, goats and sheep are run together and the use of both species is a distinct possibility for both practical and economic reasons. In very arid environments, however, goats tend to survive longest under the extreme climatic conditions and the deteriorating feeding conditions.

In terms of meat production, the question of the number of kids or lambs born and the amount of meat that can be sold annually from the breeding flock is very real and affects the choice of species. This is also influenced by the relative price of meats and the market demand for the product. Biomass production is dictated by a number of biological factors, including age at first breeding, interval between parturitions, litter size, lifetime productivity, and mortality.

REPRODUCTIVE EFFICIENCY

The task of maximizing numbers and ensuring survival is a particularly important strategy to increase the productivity of both species. It is also an important component of producing numbers for breeding and marketing reasons. Thus, improvements to reproductive efficiency can significantly influence the objective of increasing numbers born and product outputs. Reproductive rate is the all too important factor and the build up of numbers is associated with the following components: age at first mating (females), productive life span of males and females, annual mortality in the breeding flock, and number of young females reared per 100 breeding females. The last component is, in turn, influenced by percent of breeding females failing to bear, percent of breeding females producing multiple births, frequency of parturition, and mortality rate up to first mating.

Based on the breeds available (Devendra 1986), there are at least four breeds each of goats and sheep that are distinctly prolific. Much more use can be made of all these breeds to increase the contribution from both species.

Increasing fertility or number of offspring born per female per kidding or lambing is important because this significantly influences the profit margins. This point was demonstrated in calculations with 80, 100, 120, and 140% rates of fertility for goats in Malaysia. The gross margin of profit per flock or per breeding doe increased with fertility level and type of feeding system (Devendra 1976). Lifetime productivity is essential and females must be retained in the flock long enough (5-7 years of age) to express their genetic capacity.

The significance of varying litter size because of inherent genetic capacity is reflected in a comparison between goats and sheep in Malaysia in terms of biomass production. Biomass production is the net effect of combining the inherent biological qualities in the species as well as good husbandry. It is influenced by such factors as age at first breeding, length of reproductive cycle, interval between parturitions, litter size, lifetime productivity, and mortality. It is, therefore, of interest to compare the relative abilities of both species to produce biomass, a portion of which is sold for profit as meat (Table 1). It is evident that although the average live weight of adult does or ewes is the same, litter size is an important determinant of biomass production when other factors such as the level of husbandry and mortality rates are similar. In this case, goats produced about 82% more biomass than sheep in Malaysia.

FEEDING AND NUTRITION

Attention to feeding and nutrition, and the development of suitable strategies that can alleviate the prevailing low efficiency of production represents a particularly important strategy. Once the production objectives have been defined and the appropriate choice of species has been made, the efficiency with which the production resources are used and the response of the species to this efficiency, in terms of increased per animal productivity, will be largely dictated by the level of feeding and nutrition. In this context, the attention to feeding and nutrition is the most important single factor that affects production, including reproductive efficiency. While breeding and selection programs are long term, the benefits of improved feeding and nutrition are spectacular and relatively

Table 1. Comparative biomass production between indigenous goats and sheep in Malaysia.

Species	Avg live weight of female	Litter size	Surviv-ability at 12 months[a]	Avg weight at slaughter (kg)	Biomass production[b] (kg)
Goats	22	1.8	1.44	20	28.8
Sheep	22	1.1	0.88	18	15.8

Source: Devendra (1985b).

[a] Mortality rate is 20%.

[b] Survivability x average weight at slaughter.

immediate. It is relevant, therefore, to consider this topic in some detail.

Nutritional strategies are the most important nongenetic factors that can influence future small ruminant productivity in the Asian region. Once a breed or species has been identified, the efficient utilization of the available feed resources is the most important next step in addressing productivity.

The justification for emphasizing feeding and nutrition is seen in the results of two studies in India and Malaysia (Tables 2 and 3). In India, in both breeds, the differences in the average milk yield per lactation between the high and low planes of nutrition were very high, between 226 and 315% (Table 2). It is significant to note that with the low plane of nutrition the effect was to curtail milk production. In Malaysia, a comparison of adult goats of approximately similar ages from the rural areas and those reared "under" experimental conditions gave very high differences (Table 3).

The following four strategies are considered important.

Increased Utilization of Crop Residues and Agroindustrial By-products

More intensive use must be made of the large amounts of lignocellulosic materials and other agroindustrial by-products, simply because these are the cheapest and most widely available

Table 2. Effects of nutrition on lactation milk yields (litres) of two dairy breeds of goats (Barbari and Jamnapari) in India.

	Barbari			Jamnapari		
Lactation number	MH[a]	LL[b]	Difference (%)	HH[c]	LL[b]	Difference (%)
1	101.0	27.8	263.3	153.7	44.0	249.3
2	129.7	30.3	328.1	196.0	58.4	235.6
3	100.4	21.7	362.7	131.8	45.2	191.6
4	106.8	-	-	128.0	-	-
5	109.2	-	-	-	-	-
Mean	110.4	26.6	315.0	160.5	49.2	226.2

Source: Adapted from Sachdeva et al. (1974).
[a] Medium-high plane of nutrition.
[b] Low-low plane of nutrition.
[c] High-high plane of nutrition.

feeds for ruminants. This conclusion has been previously emphasized (FAO 1982; Mahadevan 1982). For successful application, acceptable feeding systems are simple, practical, within the limits of the farmers' capacity and resource availability, convincing, and consistently reproduceable. Moderate to low levels of animal performance may be biologically inefficient, but could be more economically viable than high levels of performance, especially with the existing limitations of small farm systems.

Not enough use is being made of the various crop residues and agroindustrial by-products to feed both goats and sheep. This is possibly due to an inadequate use of intensive feeding systems such as that which has been successfully demonstrated for rice by-products or maize by-products fed with Leucaena leucocephala in the Philippines (Rasjid and Perez 1980; Magay 1982) and sugarcane by-products fed to goats in Fiji (Hussein et al. 1983).

Table 3. Magnitude of improvement feasible in indigenous Katjang goats from rural araes as a result of improved nutritional management in Malaysia.

Parameter	Rural goats[a]	Experimental goats[a]	Improvement feasible (%)
Live weight at slaughter (kg)	18.6	28.6	53.8
Hot carcass weight (kg)	8.2	14.7	79.3
Dressing (%)	44.2	51.3	7.1
Weight of meat (kg)	5.5	8.1	47.3
Meat-bone ratio	4.1	4.9	19.5
Forequarter (kg)	1.2	2.9	108.3
Hind leg (kg)	1.2	2.2	83.3
Total edible weight (kg)	13.2	18.2	36.8
Total saleable weight (kg)	17.9	24.0	34.1

Source: Devendra (1979).
[a] Adult goats about 3 years of age.

One of the problems related to alternative nutritional strategies is the choice of options. In many parts of Southeast Asia, in situations where mainly rice straw exists, the priority is finding the best means of converting rice straw to a useful animal product. Rice straw will continue to be used by cattle and buffalo, with their higher production potential (meat, milk, and draft power). This does not, however, preclude small ruminants, since using rice straw as a small ruminant feed on experiment stations has been effective. The central aim is higher levels of production, since energy requirements for maintenance account for most of consumption, particularly with animals of low production.

In light of recent Asian results, the choice of options also needs special attention with respect to feeding systems: i.e., urea treatment of rice straw and urea-molasses block licks (UMBL). Rice straw may also be improved by microbial degradation.

Improving the nutrition of sheep and goats would also reduce disease incidence and mortality. This, in turn, should reduce economic losses.

Increased Forage Cultivation on Available Land

Where possible, there should be increased cultivation of forages, grasses, and legumes on available land. This can be undertaken in any waste or uncultivated land, rice bunds, or fence lines. The use of leguminous forages like leucaena (*L. leucocephala*) or sesbania (*Sesbania grandiflora*) is underestimated and much more use could be made of these, especially as supplements (Devendra 1984). *Leucaena leucocephala* is the most widely used forage for feeding ruminants in Southeast Asia (Devendra 1986) and, even during droughts, provides an excellent source of fodder and dietary nitrogen; it can also be used as a fence line. The presence of such forage reserves forms an important component of integrated agriculture in small farms and goes a long way toward furnishing much-needed nutrients to enhance intake and animal performance. Throughout the Asian region, there exists a variety of tree leaves whose use is underestimated (Table 4), especially for feeding goats (Devendra 1983a).

The basic strategy is to produce sufficient amounts of good-quality feed available year round (Devendra 1986). On small farms, the demand for food crops supercedes production of feeds for livestock. Thus, innovative measures are needed for meeting nutrient requirements of livestock from various forages and residues from food-crop production. This approach also has the associated advantage of enabling seasonal surpluses (e.g., cereal straws or silages) to be preserved for subsequent use when feeds are in short supply, such as during dry seasons and droughts.

Increasing the Use of Dietary Nitrogen Sources

Associated with the first two strategies is the important need to concurrently increase the use of dietary nitrogen sources, especially nonprotein nitrogen (NPN) sources and proteinaceous forages. Examples of the benefits of this strategy are seen in the results of two previous studies (Tables 5 and 6).

Table 4. Some important tree leaves and browse plants in South and Southeast Asia.

Common name	Botanical name
Bangladesh, India, and Pakistan	
Anjan	*Hardwickia binnata*
Ardu	*Ailanthus excelsa* Roxb.
Babul	*Acacia arabica*
Bauhinia	*Bauhinia* spp.
Banana	*Musa* spp.
Bargad or banyan	*Ficus bengalensis*
Beri	*Ziziuphus jujuba*
Dhaincha	*Seshania aculeaton*
Gular	*Ficus glomerata*
Imli	*Tamarindus indica*
Jackfruit	*Artocarpus heterophyllus*
Jamun	*Engeinia jambolana*
Kheiri	*Prosopis cineraria*
Khair	*Acacia catechu*
Khanthal	*Artocarpus integrifolia*
Mulberry	*Morus indica*
Pakar	*Ficus infectoria*
Pipal leaves	*Ficus religiosa*
Neem	*Azadirachta indica*
Sainjan	*Moringa oleifera*
Siras	*Albizzia lebbeck*
Indonesia, Malaysia, Philippines, and Sri Lanka	
Banana	*Musa* spp.
Banyan	*Ficus bengalensis*
Canna	*Canna* spp.
Cassava	*Manihot esculenta* Crantz
Gliricidia	*Gliricidia maculata*
Hibiscus	*Hibiscus rosa-sinensis*
Ipil-ipil	*Leucaena leucocephala*
Jackfruit	*Artocarpus heterophyllus*
Lantana	*Lantana* spp.
Passion fruit	*Passiflora edulis* f. *flarcarps*
Pigeon pea	*Cajanus cajan*
Singapore rhododendron	*Melastoma malabathricum*

Table 5. Effect of feeding untreated and urea-ammonia treated grand rice straw on the average daily weight gain of young goats.

Treatment[a]	Daily live weight gain (g)	
	9 weeks	13 weeks
75% URS, 25% CL	53a	45a
50% URS, 50% CL	91b	92b
75% TRS, 25% CL	93b	84b
50% TRS, 50% CL	105b	101b
100% TRS	11c	27a
SE	10.3	10.4

Note: Means in the same columns followed by a different letter differ significantly ($P < 0.05$).

Source: Adapted from Winugroho and Chaniago (1983).

[a] URS, untreated rice straw; TRS, treated rice straw; CL, cassava leaves; SE, standard error.

In the study of Winugroho and Chaniago (1983), goats were fed untreated and urea-ammonia treated straw supplemented with cassava leaves in Indonesia (Table 5). The inclusion of up to 50% cassava leaves with treated or untreated rice straw, while stimulating increased weight gain, was not statistically different between treatments over 9 and 13 weeks experimental durations. It follows that the inclusion of cassava leaves with untreated rice straw is cheaper than its inclusion with treated straw. It was concluded that grinding and urea-ammonia treatment of rice straw enabled goats to maintain weight. However, the inclusion of cassava leaves in diets with untreated and treated rice straw enabled pelleting of the feeds and allowed the goats to gain weight.

The study of Devendra (1983) involved another example of feeding a proteinaceous, leguminous forage, *Leucaena* leaves, in balance trials with sheep. Increasing levels of *Leucaena* forage (10-60%) were used to substitute the basal rice straw

Table 6. Intake and digestibility of chopped rice straw (RS) supplemented with varying levels of *Leucaena* leaves (L).

Parameter[a]	RS (control)	RS + 10% L	RS + 20% L	RS + 30% L	RS + 40% L	RS + 50% L	RS + 60% L
Fresh intake (g/day)	741.3a	890.7ab	967.7ab	1158.7ab	1446.0bc	1475.7bc	1300.7bc
DMI/kg 0.75 (g/day)	59.9a	58.9a	53.2a	59.9a	68.5b	70.7b	59.9a
DMI (% body weight)	2.7a	2.6a	2.6a	2.8a	3.1a	3.1a	2.7a
DM digestibility (% of intake)	42.2a	58.5b	46.7b	49.5b	50.5b	53.2c	49.6b
OM digestibility (%)	50.9a	51.3a	49.5a	52.5b	53.3b	55.5b	52.4b
CP digestibility (%)	19.7a	40.5b	47.2c	49.6c	52.0c	66.2d	50.5c
Energy digestibility (%)	40.4a	46.4b	46.3b	52.1c	51.5c	54.7c	46.2b
N retention (% of intake)	-0.1a	20.2b	16.4b	23.6b	31.5c	27.5c	30.8c

Note: Means in the same row followed by a different letter(s) differ significantly ($P < 0.05$).

Source: Devendra (1983).

[a] DMI, dry matter intake; DM, dry matter; OM, organic matter; CP, crude protein.

feed. Dry matter intake (DMI), crude protein and energy digestibilities, and N retention were all improved. The calculated increase in metabolizable energy (ME) intake because of *Leucaena* supplementation ranged from 16.2% with the 10% inclusion to 86.2% for the 50% *Leucaena* leaf inclusion (Table 6). N retention also increased with increasing *Leucaena* level, reaching a maximum at the 40% level of inclusion; this was concluded to be the optimum level.

Concerning NPN sources, much more use could be made of urea and poultry litter, both of which are relatively cheap and within reach of farmers. It has been estimated there is an annual production of approximately 13.1 x 10^6 kg poultry litter, equivalent to 3.2 x 10^2 kg crude protein, in Asia and the South Pacific (Devendra 1985c). A good proportion of this can also be incorporated in diets for goats and sheep.

Increasing the use of NPN sources can be achieved by employing one of several methods appropriate to a particular situation. Some applicable methods are spraying to pasture, spraying or addition to hay, addition of NPN to a liquid trough in association with molasses, using NPN-molasses block lick, inclusion in drinking water, and addition to cereals or concentrates.

Of these, the incorporation of urea into cereal straws to release ammonia, the spraying of ammonia directly into the cereal straws, and the use of urea-molasses block licks (UMBL) has had considerable success. These innovations are significant in that they represent two major success stories in Asia.

The success of UMBL is mainly because of their attractiveness and taste to the livestock. The blocks are a potentially effective means of making NPN such as urea (15-20%) continuously available, and fortified with macro- and microminerals and other nutrients essential to both the microbes and the animal. The possibility of overingestion of the flock and the danger of toxicity appear to be remote.

Much of the early work in this area has been confined to buffalo and cattle in India, the Philippines, and Indonesia. Recently, however, an attempt has been made to extend the use of UMBL to small ruminants; three recent preliminary experiments on this possibility, conducted by Soetanto (1986) in Indonesia, are possibly the first of their kind. In experiment 1, the results of digestibility studies with sheep given waffered sugarcane tops (WST) with or without UMBL with

0, 3, or 6% urea and 500 g Leucaena indicated that there was an increase in the dry matter disappearance in sacco of WST. The results, however, were not significant. In experiment 2, four growing lambs were placed on each of three treatments: control (+300 g fish meal), WST + UMBL (3% urea), and WST + UMBL (6% urea). The results indicated that UMBL significantly stimulated ($P<0.01$) live weight gain (Table 7). Experiment 3 was similar to experiment 2, using goats instead. This experiment was terminated, however, because of ill health of the goats. These preliminary studies suggest that the use of UMBL can be extended to goats, especially in extensive situations where the feeds are coarse and sparse. This strategy should be substantially expanded in terms of future effort.

Strategic Use of Supplementary Protein Sources

Strategic use of protein supplements, often the main limiting factor in efficient feeding and nutrition of ruminants, also merits some consideration. Its economic use for both goat meat and mutton production must be carefully considered, especially in relation to breed type and potential for growth. With milk production, however, judicious supplementation is necessary ensuring that the value of the milk produced is higher than the cost of the supplements used.

The importance of the decision to supplement is seen in the results of a recent study in India. The treatment involved feeding either green forage, concentrates, or green forages and concentrates to a control browsing situation. Treatments, as would be expected, significantly stimulated daily live weight gains and also affected dressing percentages ($P<0.05$). The net returns indicated that the supplementary feeding with forages gave the highest margin of profits, followed by concentrates, and, finally, the combined effect (Table 8). The results emphasize the value of green forages and question the necessity of feeding concentrates for meat production from sheep in this experiment.

An alternative situation involves the strategy to arrest live weight losses during drought. This has been well demonstrated by Vearasilp (1981), who showed quite clearly that when high-quality Leucaena or Gliricidia was included between 10 and 20% of dietary dry matter in a rice straw based diet, live weight losses by sheep were small over a 45-day period.

The strategy to use scarce concentrates carefully implies that protein concentrates like coconut cake, groundnut cake,

Table 7. The effect of urea-molasses block licks (UMBL) supplementation on feed intake and daily gain of lambs in Indonesia.

Diet[b]	DM[a] intake (g/day)		OM[a] intake (g/day)		Daily live weight gain (g)
	WST[c]	UMBL	WST[c]	UMBL	
A	224.94	88.74	186.27	81.07	-35.40
B	236.64	91.81	209.57	83.87	18.57
C	283.27	116.69	234.15	106.47	23.60

Source: Adapted from Soetanto (1986).

[a] DM, dry matter; OM, organic matter.

[b] A, natural grass ad lib + 300 g fish meal; B, UMBL + 3% urea; C, UMBL + 6% urea.

[c] WST, waffered sugarcane tops.

soybean meal, palm kernel cake, and fish meal, all of which are commonly found in most countries, can be conserved and preferentially utilized more efficiently by nonruminants. Some of these ingredients may need to be protected for local use rather than be exported.

EXPLOITING THE AVENUES OF PRODUCTION

Three main types of production systems have been previously described (Mahadevan and Devendra 1985). Of these, exploiting systems integrated with tree cropping appears to have potential for substantially increasing the productivity of goats or sheep.

There currently exists in South and Southeast Asia 20.3×10^6 ha of land under permanent crops (FAO 1984). This area is essentially unused and is potentially valuable if some of it can be integrated with either goats or sheep for meat production using the available knowledge and suitable interventions. Assuming an average stocking rate of four goats or sheep per hectare, which is typical of stocking rates involving

Table 8. Performance of weaner kids in a semi-arid environment in India.

Parameter	Browsing (B)[a]	B + forage	B + concentrates	B + forage + concentrates
Initial weight (kg)	12.0	10.9	12.7	12.5
Final weight (kg)	13.8	14.7	22.8	22.3
Weight gain (kg)	1.8	3.7	10.0	9.7
Avg daily gain (g)	19.4	41.7	111.0	108.2
Dressing (%)	45.7	44.5	48.2	49.1
Returns per kid per 90 days	-	9.0	3.6	0.2

Source: Parthasarathy et al. (1983).
[a] For 7 h daily.

natural vegetation under coconuts and rubber based on a review of the literature (Devendra 1985b), and if only half this land area (10×10^6 ha) was integrated with one of the species, the corresponding number of goat or sheep equivalents is 40×10^6. At an approximate slaughter weight of 20 kg, the potential biomass production is 800,000 t, which represents about 79% of the combined current production of goat meat and mutton from goats and sheep in South and Southeast Asia. It is patently clear, therefore, that the avenue of production can be exploited much more fully and merits a high priority in research and development programs.

Likewise, a system that should be more fully investigated is intensive stall feeding or the "cut and carry" system. This system is favoured by increasing demographic pressures, reduced grazing land, and the presence of considerable quantities of crop residues and agroindustrial by-products, including nonconventional feeds. The available crop residues and nonconventional feeds are not being used adequately in intensive feeding systems; their use must be substantially expanded.

For both systems in particular and all systems in general, there must be multidisciplinary effort and an application of the information that is already on hand to achieve the final objective of maximizing productivity from both species.

EXPORT MARKETS

A major initiative that requires attention and one that has not been given the attention it deserves is the question of export markets for goat meat and mutton. Admittedly, the first priority is to maximize production of meat from both goats and sheep to meet national targets. Markets beyond national boundaries, however, can also be considered. Market potential in the Near East is enormous and warrants an immediate initiative. This initiative must consider the following aspects: type of meat required (goat meat or mutton); methods of slaughter, processing, and transportation; live animals or frozen carcasses; aspects of carcass quality and taste preferences; and economic benefits of the export trade.

These considerations and the quest to increase productivity from small ruminants through more intensive systems of management encourage yet another aspect of the production system that has not been adequatly considered in the past: commercialization of large-scale meat production comparable to beef enterprises. This aspect has not been given the attention it deserves; to take advantage of the available dietary ingredients, much more research and development are required. The inherent advantages of this approach include a more complete utilization of the available feeds, the development of more intensive systems of production including better use of the meat breeds, and an expanded production of meat in quantitative and qualitative terms for both the national and especially international markets in the Near East.

Some consideration has already been given toward meeting this objective, especially in Pakistan and India, but further progress must be sustained. In Pakistan, large sheep feed lots are now being examined in Buluchistan and the Northwest Frontier Province using mainly nonconventional feeds, such as depathogenized poultry litter, concurrent with the development of slaughter facilities. Such initiatives can conceivably also be expanded to include other countries in Asia, provided the production resources can be coupled to economic meat production from small ruminants. Perhaps the overriding consideration in this initiative is the element of urgency that is required to grasp the existing demand potential in the Near East. Once this initiative has been grasped, it will be necessary to sustain production and strive toward improving the quality of the meat produced to meet consumer preferences.

INFRASTRUCTURE, RESEARCH, LINKAGES, AND TRAINING

A strong infrastructure is essential to support research and development programs. Continuing research is vital to sustain progress not only nationally, but regionally, in which linkages can promote further progress. Large-scale, on-farm testing is also necessary and, for the results to be accepted, they must be convincing, consistently reproduceable, and within the limits of the farmer's capacity and resource availability. Inherent within all these strategies is suitable training to ensure the effectiveness of the total effort.

One aspect of the support services that needs revamping in many countries is the extension services. Often the application of useful knowledge is impeded by inadequate extension services. Adequate extension services are an integral part of all development programs, including disease diagnosis and animal health provision, sale, marketing arrangements, and producer and marketing cooperatives.

CONCLUSIONS

There are a number of possible strategies that can be employed to increase productivity and, hence, the potential contribution of small ruminants. Some of these possibilities are clearly more important than others and, therefore, justify urgent attention: definition of production objectives, reproductive efficiency, improved nutritional management, and exploiting the avenues of production. Of these, the highest priority must be given to exploiting systems integrated with tree cropping more completely.

It has been reported (CGIAR 1985) that the projections for the demand for sheep and goat products up to the year 2000 indicate that the gap between production and consumption is increasing faster than for other food commodities. This conclusion is presumably based on current trends in population growth and prevailing patterns of consumption of goat meat and mutton. This trend is likely to result in 29 and 21% increases in the goat and sheep populations, respectively, by the year

Table 9. Projected goat and sheep populations (millions) in South and Southeast Asia and the South Pacific.

Category	1984[a]	1986[b]	2000[b]	2000[c]	Normal increase[d] (%)	Potential increase[d] (%)
Goats	136.2	142.0	183.7	236.3	29.4	66.4
Sheep	73.2	75.2	90.8	140.1	20.8	86.3

[a] Source: FAO (1984).

[b] Based on annual growth rates of 2.1 and 1.5% for goats and sheep, respectively.

[c] Potential increase because of integration of goats and sheep with permanent crops (see text for explanation).

[d] From the base year, 1986.

2000 (Table 9). However, if innovative improvements could be immediately made to focus on the more potentially important production systems such as integration with tree cropping involving the 20.3×10^6 ha under permanent crops, goat and sheep populations could increase by 66 and 86%, respectively, by the year 2000. This increase could make a major impact on food production and significantly alleviate the prevailing low levels of production.

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RESEARCH METHODOLOGY AND REQUIREMENTS FOR SMALL RUMINANT PRODUCTION SYSTEMS

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Abstract *The types of information required and methods available for studying small ruminant production systems within the context of a farming systems research approach are outlined. Emphasis is given to methods suitable for on-farm research. The major socioeconomic data required and the problems associated with their collection by survey are discussed. Specific animal-production information is required on population structure in the area being studied; then, for the farms, or villages if very small farms are involved, details are needed on population dynamics, existing productivity, health, and housing. The responses of the animal characteristics to changes in management systems are normally estimated from observational studies and on-farm experimentation, but there are severe limitations to data obtained in this way. Methods for collecting and interpreting these data are outlined and the value of systems modeling as an aid to the design of improvement programs is discussed.*

There is general agreement that farming systems research aims to take a global approach and examine all the farm enterprises acting together in the context of the socioeconomic, managerial, and physical environments. Within this framework, the small ruminant production system can be investigated as a subset as long as the interrelationships with other components are taken into account (Norman and Collinson 1985).

Farming systems research and any of its subsets rely heavily upon on-farm investigations, particularly for initial situation analysis, problem definition, strategy testing, and demonstration. The knowledge used to develop the new strategies is usually drawn from the store of existing information gained from research (both station and on-farm) and experience. In many cases, however, this will not be sufficient and there is increasing interest in the use of on-farm studies because of the hopefully greater likelihood that the information being sought will be relevant to the farming situation and the results will be achievable on other farms.

The literature on farming systems research often appears to be very general and discussions of methodology sometimes lack specific details. This is undoubtedly a result of the wide scope of any systems investigation and the limited space given to authors. It is the intention here to focus on methods for investigating small ruminant production systems, with limited attention being given to socioeconomic aspects.

INFORMATION NEEDED FOR SMALL RUMINANT SYSTEMS

The information required for investigating possible improvement strategies for small ruminant systems can be divided into two main sections: one dealing with data defining the current situation and the other dealing with likely responses to changes in any part of the system.

Socioeconomic data are required to establish the system in its "real-world" context, to allow the assessment of the external impact of any changes, and to help guard against any irrelevant or unacceptable changes being recommended. Economic data are needed to assess and integrate individual farm activities and to evaluate markets and their likely development.

Regional and individual farm population structures and management systems must be defined. This includes the distribution of breeds and types, age and sex structures, and products generated. Overall information on the feed resources available and the relationship between small ruminants and other stock also must be established.

The population dynamics and production levels of the sheep and goats kept on the individual farms are important and, ideally, are needed on an age-specific basis. Data on the health of the animals, their housing, and problems related to them should also be specified.

All this information will form the basis of a situation analysis that will often allow the main constraints to productivity (or to the achievement of farmer or institutional goals) to be identified. The formulation of strategies to overcome these constraints will then require information on the response of the various production and economic parameters to changes in the inputs or the management and structure of the population.

METHODS FOR OBTAINING AND INTERPRETING THE REQUIRED DATA

This section deals with methods suitable for acquiring relevant data in the South and Southeast Asian region, with particular emphasis on those that can be used in on-farm studies. It will be seen, however, that some essential data cannot be readily or reliably obtained from farms and it will be necessary to collect these data from research stations and other sources.

Socioeconomic Information

Practically all the information relating to socioeconomic aspects of farming and livestock production systems has been drawn from surveys of farmers from the "target" group for whom improved systems are to be developed. Considerable care is needed in the design of such surveys to ensure that the sample is representative and that the conclusions drawn will be referable to the target group and not specific to the farmers surveyed. This implies that the basic sampling method should be random and not restricted to those farmers who are accessible or most cooperative. Unfortunately, resources are usually insufficient to allow adequate random samples, so stratification is required on the basis of the main physical, agricultural, and economic classifications that exist in the target group. For example, Ashari and Petheram (1983), when surveying ruminant feeding systems in West Java, classified villages according to altitude and rainfall and the main soil and land-use types. Within such classes, villages and farmers within villages would ideally be chosen at random in sufficient numbers to ensure that the range of enterprise scale is represented. This design stage is normally based on official statistics, data maintained by local authorities, and preliminary observations of the target group and its environment. An important factor in the success of this type of survey is the involvement of people with local knowledge in the design and survey team. Indeed, Zandstra et al. (1981) maintain that farmers themselves should be involved in the whole program, particularly because on-farm research and testing of potential new systems constitute an important part of any farming systems research.

Once designed, surveys are normally conducted by interview and their success in deriving valid information depends heavily upon the skill with which the questions are framed and the tact of the interviewer. The farmers of many communities have been surveyed numerous times and their attitude to interviews can be influenced by their previous interview experience, their reluctance to discuss personal, religious, and financial matters with strangers, their trust in officials, and the time they have available to answer often lengthy and apparently repetitive questionnaires. In addition, some societies have a tradition of trying to please guests, and answers may be affected by what the individual thinks the interviewer would like to hear. Clearly, there is ample opportunity for the collection of misleading information and, if specialist help is not available from experienced sociologists and economists, it is better to restrict the scope of a survey to matters relating to the most important areas of interaction between the livestock system and its socioeconomic environment.

The main sociological information required relates to the size, sex, and age structure of each family, the education levels reached, and the religious and social functions that small ruminants fulfil. Reasons for raising sheep and goats, for ceasing to raise them, and for not expanding their numbers are also important. Economic data are needed on prices paid and received for the various inputs and products, the end uses of the animals and their products, the mix of other farm activities, land tenure, family and off-farm labour involved in small ruminant production, and the availability and cost of capital. Other important information relating to market structure, official support systems, and infrastructure development will not usually be obtained from the survey of farmers but from local administrative and regional government sources.

The collation, analysis, and interpretation of most of the sociological and managerial data obtained from surveys are often difficult. Published results tend to use broad classifications and be largely descriptive. Where summary statistics are calculated, measures of variability other than ranges are usually not provided and it is likely that the standard statistical probability statements are not appropriate. Thus, interpretation depends upon the experience and ability of the researcher and is open to more conjecture than is normal for traditional biological research. When it comes to predicting the sociological effects of changes in livestock systems, the situation is worse as there is no formal methodology for estimating reliability.

Population Structure and Available Resources

The existing structures of the sheep and goat populations in the area and on the farms being studied must be established. On a regional basis, the breeds and types used, their numerical strength and distribution, and the major feed resources and raising systems used are all relevant because they provide the framework within which the farms operate. They will also identify the source of additional stock needed, the market for the sale of breeding stock, and market competitors influencing prices received for products. This information will usually be drawn from public statistics or perhaps large-scale surveys.

It is at the individual level of information gathering in this area that on-farm research really starts. It is possible to obtain by survey some of these data and some information on animal productivity and health outlined in the following sections. However, too much reliance should not be placed on data derived in this way unless specific favourable circumstances exist and additional validation studies are carried out. In general, data on animal production structure and productivity that are drawn from surveys of intensive production systems may be reasonably accurate because of the small numbers involved and their importance to the farmer. Even in these situations, however, it is unwise to rely solely on recollections of birth dates and reproduction rates over long periods; in extensive farming systems, where larger numbers are involved, information will not be accurate. Knipscheer et al. (1984) provide an example of how survey data can be validated by checking subsamples of farmers with more intensive monitoring. Because of these difficulties, on-farm studies are needed to establish the basic population parameter; however, as they can be obtained with more detailed investigations of production, they will be discussed in the next section.

Population Dynamics and Production

This section deals with methods for on-farm assessment of the main parameters of population dynamics, growth, and productivity of small ruminants. The important aspects of estimating feed availability and intake are discussed by Coop (this volume).

Population dynamics refers to the way changes occur in the size, age, and sex structure of a population. The main parameters are age at first breeding and reproduction, death, and extraction (by the farmer) rates. For a thorough study, these rates are needed on an age-specific basis, but alternative, less accurate methods are available if the detailed information cannot be obtained. For predicting population changes and availability of surplus stock, comparing systems, and diagnosing problems, these parameters can conveniently be combined into the index, net reproductive rate, used by ecologists in population studies. Adapted for small ruminants, this can be defined as the number of potential replacement females produced by a breeding ewe or doe during her life in the population. If the net reproductive rate is greater than 1.0, the population can increase or surplus females will be available for sale; if net reproductive rate is less than 1.0, the breeding population will decrease.

In practice, it is almost impossible to estimate age-specific reproductive parameters on farms and it is extremely difficult on research stations. Data must be collected from a large number of breeding animals over many years to separate age and year effects and to ensure that the years covered represent an adequate random sample. Furthermore, the statistical procedures are complex and usually require powerful computing facilities.

Despite these problems, it is possible to make estimates of net reproductive rate where large populations are available in extensive systems or if the several farmers' flocks within a village are considered as one population in the smaller intensive systems. In the region being considered, year-round matings are normally practiced, so annual lambing or kidding percentages are difficult to calculate and cannot easily be used to estimate lifetime performance. Instead, the following data should be recorded for all females: age at first mating, age on leaving the breeding population, number of offspring produced in this time, and deaths of young females between birth and first mating. From these data, the net reproductive rate can be calculated. The natural logarithm of net reproduction rate divided by the female generation length (approximated by the average age of the breeding females) gives the coefficient of capacity to increase, from which potential changes in breeding numbers can be estimated. If desired, an annual reproduction rate can be estimated by dividing the average number of offspring produced during life by the length of time in the breeding population.

It has already been pointed out that these data should be collected from on-farm observations rather than from surveys.

Where this is done, it is often also possible to record the circumstances relating to the various events, which can greatly help in identifying problems. For example, short female generation lengths may be due to high sale and slaughter rates or unusual mortality and the strategies proposed to overcome these circumstances would be quite different. Similarly, in smallholder systems, many farmers will not own a breeding ram or buck, so females in oestrus must be taken to the male in seasons when animals are confined. Thus, efficient oestrus detection and the farmers time become important influences on reproduction, which good observational records can identify. Regular records of body weight, seasonal, and feed conditions are also important for on-farm investigations of breeding performance.

Emphasis is given to reproduction because of its basic importance in the maintenance of stable populations and the fact that it is the surplus animals that meet the farmers needs for trade and social requirements. It is also clear, however, that other aspects of productivity of individual animals are important. Growth of young animals, the body weight and, hence, meat production reached, lactating ability where milk is harvested, and, in special cases, fibre production should all be assessed. It is not as difficult to record these features and smaller samples can be used. Thus, they can readily be included in programs designed to measure the breeding performance of small ruminant populations.

Health

The relative importance of health problems in small ruminant production systems of the region is poorly documented, although much is known about the various disease and "subclinical" health conditions that can occur. On-farm research is the only way that this type of information can be obtained and there are well-established epidemiological methods available.

In general, epidemiological studies aim to investigate the prevalence and distribution of disease and identify the factors that influence its occurrence and spread. The information required for this work includes records of the incidence and attack rates, distribution through the villages and farms of the area, the immunological status of the population, the presence of vectors or intermediate hosts, types and condition of housing, and the climatic conditions before and at the time of disease. Full-scale studies require considerable resources of trained workers and laboratory support, but more simple studies can be very effective if based on observations made at local abattoirs as well as on-farm records. In either case, experienced veterinarians are required at the field level and particular attention should be paid to those aspects of nutrition, management, and housing that can be altered in redesigned production systems.

Housing

Housing of small ruminants is generally only a feature of intensive village production systems, except where animals in extensive grazing systems are herded into pens or shelters for protection at night. Little research into the design of sheep and goat housing has been reported, although much is known about the effects of climate and the immediate environment on the physiology of these animals. It is difficult to carry out scientifically acceptable on-farm research into the effects of housing on production because the experimental units are the houses being compared and not the individual animals within each house. Thus, it is almost impossible to obtain sufficient numbers for valid statistical tests, so reliance must be placed on observations of the animals' physiological condition and the interpretation of these in the light of known relationships between physiological stress, productivity, and health.

RESPONSES TO CHANGES IN MANAGEMENT SYSTEMS

So far, this paper has emphasized the acquisition of information that establishes the existing characteristics of small ruminant production systems and the animals within them. From this information, it is often possible for experienced workers to identify improvement areas and draw on the existing body of knowledge to design new systems. Where this is done, the general aim is to produce a better system but not necessarily the best possible. It is frequently found, however, that existing knowledge is not sufficient. Most livestock research with small ruminants has been done in the developed counties, where the temperate climates, the breeds and types of animals, the stresses they experience, and the farming systems are vastly different from those of South and Southeast Asia. Even then, there is little detailed information on the productivity of goats, except for aspects of lactation in dairy types. Consequently, there is a need for research on the responses of small ruminants to changes in management systems.

Most of the available research information has been derived from institutional research stations and this is often criticized as lacking relevance to real farm problems. Furthermore, this work tends to focus on isolated components of the farm system and the responses obtained are often not achieved to the same extent when applied on farms. Thus, there is considerable interest in obtaining information from the farms for which the improved systems are to be designed. While this aim is admirable, there are important problems relating to the control of animals and treatments and the scale of investigation possible that make some studies impossible; these problems must be considered when planning on-farm research.

Research that aims to quantify response to changes in management can be classed as observational studies of animals in existing different conditions or as studies of imposed treatments in designed experiments. To date, most on-farm work with animals has been of the first type.

Observational Studies

An important aim of comparing animals in different existing conditions is to predict the future response to the imposition of similar differences. It is important, however, to realize that cause and effect cannot always be implied from such studies and that there may be several explanations of the observed differences. This is particularly so where different management systems are being compared that involve different farms or even villages. In general, statistical analyses are not meaningful as the true replicates are not the individual animals within systems and the systems themselves are seldom replicated. In these cases, the various statistics give useful measures of variability within a system but do not help interpret differences between them.

Another type of study that is in this category is the analysis of relationships among characteristics of the animals within the farming systems. Relationships of productivity to body weight and perhaps condition score are especially important as they are often used to predict the likely response to management changes that have measurable effects on feed availability and quality. Again, it should be realized that the relationships identified in this way are based on existing variation in each character and the covariance may be due to special circumstances that might not be repeated when changes in body weight are caused by imposition of a new management system. This emphasizes the need for validation of predictions using independent data.

Experimental Studies

On-farm experiments can be used to derive information on components of the livestock systems that are to be designated and, ideally, they should be used to evaluate any new system being proposed. Unfortunately, there are great operational problems in anything other than very small-scale experiments, but their potential relevance and farmer involvement make it important that they be attempted. The main considerations are that objectives should be as simple as possible and consistent with the production of useful information, and that as many inputs and resulting products as possible be measured to facilitate interpretation.

Planners of on-farm experiments should recognize that it is difficult to satisfy the requirements of traditional scientific experimentation, particularly in relation to replication and statistical analyses of data. These problems can be illustrated with an example of a comparison between 2 systems with 3 replicates of 10 animals each. The statistical analysis of this design is given in Table 1. The expected values of the mean squares shows that the correct error term to use to test the difference between systems is the replicates within systems. Unfortunately, this analysis is not very powerful, with only 2 degrees of freedom, yet the experiment would be a major undertaking. In most cases, no replication of the system is made and the variance between animals within systems is used as error. This is the same as pooling the sums of squares and degrees of freedom for replicates and animals in the example. Unfortunately, this contains only a small fraction of the true between-replicate variance and does not give a valid test.

Despite these considerations, the importance of the systems data to be derived from on-farm experiments is so great that investigators should not abandon the work if replicates cannot be established. When large differences are sought, there is valuable information to be derived from a comparison of the system means and a measure of the animal variance. Interpretation of these data, however, relies heavily on the experience of the investigator. It is not assisted by an inappropriate statistical analysis.

In some cases, it is possible to design reasonably powerful experiments with small numbers by techniques such as repeating measurements in successive periods (Gill 1978). The example in Table 2 shows that care must be taken with allocating the correct error terms. Here, the experimental unit is

Table 1. Analysis of variance for comparing systems.

Source of variation	df[a]	Example[b]	E (mean squares)[c]
Systems	s-1	1	$V + aV_r + arS$
Replicates within systems	s(r-1)	2	$V + aV_r$
Animals within replicates	sr(a-1)	54	V

[a] s, number of systems; a, number of animals; r, number of replicates.

[b] s = 2; r = 3; a = 10.

[c] V, variance among animals; V_r, variance among replicates; S, mean-squared differences of systems from overall mean.

not the same as the observational unit and the latter is not independent. The overall treatment difference is not powerful, but if a meaningful hypothesis can be made about the treatment x period interaction, then a much more powerful test is possible using the residual error. For example, we might test if the weight change between seasons differs from system to system. Methods for testing specific preplan comparisons of trends within the interaction are given by Gill (1978). The main problems associated with this approach are the risk of losing animals and the assumption of a constant correlation between periods, which is unlikely over a long time, although there are methods to allow for this.

Similar considerations are also associated with the evaluation of different genotypes and systems that may use genetically superior sires. The apparently simple task of comparing animals from different strains should allow for the fact that differences in prenatal and early postnatal environments can affect productivity throughout life, making it necessary to breed and rear the animals together. Where comparisons are being made of progeny from sires of different breeds mated to females of one breed, genetic replicates are the sires, not the individual progeny, so there must be a relatively large number of sires and they should be identified. James (1975) has

Table 2. Analysis of repeated measurements.

Source of variation	df[a]	Example[b]	E (mean squares)[c]
Treatment	t-1	1	V(1 + (p-1)c) + apT
Animals within treatment (error 1)	t(a-1)	3	V(1 + (p-1)c)
Periods	p-1	11	V(1-c) + taP
Treatment x period	(t-1)(p-1)	11	V(1-c) + a(TP)
Residual (error 2)	t(a-1)(p-1)	66	V(1-c)

[a] t, number of treatments; p, number of periods; a, number of animals.

[b] t = 2; p = 12; a = 4.

[c] V, variance among animals; c, correlation between any two periods (assumed constant) = (error 1 - error 2)/(error 1 + (p-1) error 2); T, mean-squared difference of treatment from overall mean; P, mean-squared difference of period from overall mean; (TP), mean-squared difference of interaction mean from overall mean.

outlined the bias that is introduced if this is not taken into account. In addition, where the experiment involves a comparison of exotic and native stock via this type of progeny testing, heterosis and gene recombination for both direct and maternal characteristics can affect the relative performance of offspring. As part of the heterosis is lost when introductions of the exotic type cease, these effects should be measured so that estimates can be made of the expected productivity of any combination of the genotypes that might be used. Dickerson (1969) has outlined the various parameters that are needed, but, in practice, these parameters are almost impossible to obtain from on-farm studies. Consequently, value judgement must be used and apparent benefits from introducing a different genotype should be discounted.

SYSTEMS MODELING

In recent years, development in computer applications of mathematical models have been used to simulate livestock production enterprises within farming systems. In general, these integrate biological data from specific farms with known relationships to produce a dynamic model of the livestock system. If these models are sufficiently realistic and accurate, they can be used to examine the likely consequences of changes to any part of the system, so many "experiments" can quickly be conducted. On-farm tests can then be carried out to evaluate the most promising systems identified by the modeling.

Models that have been constructed for sheep indicate that growth, body weights, and lactation can be satisfactorily simulated given data on the quantity and composition of available feed and on the age, sex, physiological state, and potential mature body weight of the animals (e.g., Graham et al. 1979). More difficult problems are the modeling of reproduction changes and the simulation of pasture intake with interacting effects of the animals on vegetation in grazing systems. Realistic models for grazing sheep in temperate regions have been produced (White et al. 1983), but they have not been used for goat production systems in tropical environments.

It is unrealistic to expect that completely satisfactory models of small ruminant systems will be produced in the near future. However, work will continue in this area and the techniques used will be a valuable aid to those interested in designing improved systems, particularly where individual operations are small in scale and based largely on hand feeding of crop residues.

ACKNOWLEDGMENT

I sincerely thank the International Development Research Centre for financially supporting my participation in this workshop.

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RESEARCH METHODOLOGY FOR INTEGRATED SMALL RUMINANT AND TREE-CROPPING SYSTEMS

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Abstract *The methods and techniques available for measuring herbage production and utilization, and animal production under tree crops are reviewed. Relatively simple herbage clipping methods are suitable for measuring herbage mass, botanical composition, seasonal growth pattern, and annual yield. The value of oesophageal-fistulated animals for obtaining samples of what is actually eaten is stressed. Indirect in vitro methods of determining herbage digestibility are discussed: the nylon bag, rumen liquor-pepsin, pepsin-cellulase, and indigestible acid-detergent fibre techniques. Group animal intakes may be measured by "before and after" herbage clipping, but individual intake estimation is much more difficult, requiring knowledge of both digestibility and total faecal output. Carrying capacity may be determined by trial and error or from estimated annual herbage yield and animal feed requirement. No special techniques are required for the measurement of animal performance or of damage to trees or tree growth. There are, however, problems in the design, execution, and interpretation of grazing experiments. The degree of simplicity or sophistication should be appropriate to the objective required and the facilities available.*

Integration of livestock into tree cropping offers great potential, yet this potential is being realized slowly. There are technical difficulties in the maintenance and control of both the grazing and the livestock, there are some social changes to be accommodated, and there are human philosophical and attitudinal changes to be made. Integration involves replacing a relatively simple traditional monoculture with a more complex system that requires learning some new technologies and making compromises between the two components of the system: the trees and the livestock. The introduction of livestock into tree cropping in the humid tropics differs only in scale and potential from the integration of timber trees into pastoral farming now being attempted in New Zealand and Australia.

If the plantation industries are to be encouraged to adopt managed livestock systems there must be a base of knowledge and a clear demonstration of how the objective can be achieved both physically and economically. This paper is concerned with the base of knowledge: the research methods and techniques available for studying the production system. In short, this means measuring herbage production and utilization, animal performance, and the interactions of animals and trees. Most of the methods have been developed for sown pastures and rangelands, but not specifically for the vegetation under tree crops. They will cover the range of situations from relatively simple methods available for measuring herbage dry mass, growth, botanical composition, and feed preferences on smallholdings, to the sophisticated methods of measuring herbage digestibility and individual animal intake, requiring laboratory facilities, equipment, and technical skills usually available only at universities and research stations.

The value of different grass and legume species, the determination of fertilizer requirements, the influence of grazing on plant species, and similar studies will not be discussed since their determination involves the same techniques as will be described.

PLANT OR HERBAGE MEASUREMENT

Herbage Mass, Growth, and Composition

Most research work has been done on sown temperate pastures grazed by cattle and sheep, and there are reviews of this work (e.g., Meijs et al. 1982). Tropical pastures tend to be more varied and more erect and, in the special case of vegetation under tree crops, one has to contend with the rapid botanical changes from the legume cover crop to volunteer grasses, weeds, and browse shrubs more reminiscent of range-country vegetation. Techniques available for measuring tropical pastures are reviewed in Shaw and Bryan (1976) and t'Mannetje (1978).

Herbage mass

The amount of herbage present per hectare is still measured by the long-established technique of clipping. The main variants are the numbers of samples needing to be clipped to obtain acceptable representativeness and the height of clipping. The clipped samples should be separate, dried, and weighed to give percentages of plant species, leaf, stem, green, and dead material. They can be analyzed chemically.

Growth

Growth is measured as the increase in herbage mass over a given time on areas protected from grazing. To simulate as closely as possible growth under grazing, an initial herbage mass estimate is made and then a number of quadrats, cages, or enclosures are used to protect samples of pasture from grazing. These are then clipped at a later date, after which another initial herbage mass estimate is made on the grazed pasture; the process is repeated throughout the season or year. The same area must not be clipped twice. Growth estimates are important to obtain both total annual production and seasonal variation in yield, and botanical and chemical composition. The data obtained must be related to how the measurements were made, frequency of clipping, grazing pressure of the animals, and the general degree of simulation of the actual grazing process.

Range vegetation

The determination of herbage mass and growth in regions, such as range country, having a mixed vegetation containing grasses and browse shrub trees is much more difficult. There is an extensive literature on this in several parts of the world, but especially in the United States.

Methods are laborious, usually involving taking an inventory of species and edible parts of species before and after grazing. The trend has now been, in the case of browse, toward developing regression of browse yield on plant height, number of and length of branches, and stem diameter (Rutherford 1979; Holechek et al. 1982; Allison 1985).

Capacitance meters

Herbage mass and growth may also be measured through the use of capacitance meters. These measure the change in electrical capacity brought about by the intervening herbage between a probe pushed through the herbage to ground level and a metal plate or cylinder above herbage level. Many readings can be taken in a short time and these are automatically recorded (James et al. 1977; Vickery et al. 1980). It is not accurate enough for research purposes but has some application.

Visual estimation

Visual estimation has very wide application, especially in practice on farms. Human beings can be trained to estimate herbage mass by eye. Training consists of calibrating visual observation against a set of plots or pieces of turf of known measured herbage mass. Many dairy and sheep farmers in New Zealand have attended demonstrations and now regularly estimate herbage mass. Knowledge of the feed requirement of the animals enables the farmer to calculate the number of animal grazing days on hand at any time and to make relevant management decisions (New Zealand Ministry of Agriculture and Fisheries 1976). Visual estimation is also being examined in range studies. The application of this method, although it may be approximate, especially for mixed vegetation, is nevertheless a simple method for all occasions.

Plant Species Selected by Animals

A major problem and error in the determination of food value and intake of herbage by grazing animals is obtaining a representative sample of what is eaten by the animal. In qualitative terms, preferences for plant species can be observed fairly easily and probably accurately enough for practical purposes. For example, the order of preference (asystacia > grasses > legumes) has been recorded for sheep under mango and cashew in Ghana by Asiedu et al. (1978), under rubber in Malaysia by Arope et al. (1985), and under rubber and oil palm by Pillai et al. (1985). The problem lies in quantifying these differences and even more importantly in obtaining a sample of what is eaten. Before the mid-1960s, this was done by human simulation of the animal: close observation of the grazing animal and manually plucking samples.

Oesophageal fistula

Fortunately, the development of the oesophageal fistula technique altered this (Van Dyne and Torell 1964). Animals surgically prepared with an oesophageal fistula are now used to obtain representative samples of the diet selected by grazing animals. Samples so obtained are used for botanical, chemical, and in vitro digestibility analysis. At research stations or universities, it is normal to have several such animals available at any one time. They require more care and attention than do rumen-fistulated animals. Sheep are preferred to goats: their neck is a better shape, they are less stressed, and they do not rub the cannula on trees and fences. The only real doubts about oesophageal-fistulated animals are whether the sample collected in the short experimental grazing time

(<1 h) is representative of a daily intake by a normal animal and the extent to which contamination with saliva influences the composition and in vitro digestibility of the sample (Holechek et al 1982). Despite any doubts, the technique is now recognized as the best method of determining what an animal eats and of providing a sample for analysis.

Digestibility

Digestibility is the first simple measure of feed quality. It is also a component of most methods of estimating intake. Although recent thinking indicates that potential digestibility and rate of digestion may be better measures of feed quality, apparent digestibility is still the measure being used. The old method using sheep in crates is still the standard method against which indirect methods are calibrated. There are several indirect methods of estimating digestibility. The following techniques should be within the capabilities of a research station or university, but not necessarily those of a field station or plantation.

Fecal index and feed-feces ratio

The fecal index method is based on regression relationships between fecal nitrogen and digestibility. It has application for certain specific situations but is now not widely used. Of more interest now are recent developments in the indigestible marker system of determining feed-feces ratio, which formerly was based on lignin or silica. Recently, indigestible acid-detergent fibre has been shown to be a good marker (Penning and Johnson 1983), giving good agreement with actual apparent digestibilities. The n-alkenes of cutible wax have also been suggested (Mayes and Lamb 1984). All that is required is a measurement of the market in the feed (obtained from oesophageal fistula) and in a grab sample of the feces.

Nylon bag technique

This technique involves inserting a small-mesh nylon bag containing the dried ground sample through a rumen fistula into the rumen and measuring the loss in sample weight. In sheep, 2-4 samples can be done simultaneously; in cattle, up to 20 samples. The method has been used in remote situations where chemical analytical facilities are not available (Whittington and Hansen 1985).

In vitro digestion

In the previous methods, digestion is carried out in the rumen. In in vitro methods, ruminal digestion is simulated in the laboratory. The Terry and Tilley (1963) method, with minor modifications, has been used for the last 20 years. It uses as a measure of digestion the loss in weight of a dried ground sample after incubation first with rumen liquor and then with pepsin. The recent commercial availability of cellulase has led to the development of the pepsin-cellulase alternative, which obviates the need for rumen-fistulated animals (McLeod and Minson 1980; Clarke et al. 1982). It seems probable that this will supercede the Terry and Tilley (1963) method. Neither method requires elaborate equipment or laboratory skills and both give good correlations with in vivo estimates.

Measurement of Intake

The measurement of intake, or the amount of herbage eaten by the grazing animal, is an important aspect of pasture utilization and animal nutrition. Both direct and indirect methods of measurement are available. The subject has been reviewed by Langlands (1975).

Weighing the animal before and after grazing

This is an old method discarded because of inaccuracies, but now resurrected because of high technology: the availability of very accurate scales with extremely rapid microchip recording allowing live animals to be weighted to ±10 g (Penning and Hooper 1985). The animals are fitted with a harness to collect feces and urine. A correction for insensible weight loss is made. The method is still experimental but may become a practical possibility.

Estimating herbage mass before and after grazing

This method is suitable for estimation of intake of a group of animals, especially where herbage has been allowed to accumulate and is eaten off within 1-2 days, as in rotational grazing. Longer grazing periods require a correction for growth during the period to be made. For most purposes, this method is the one most commonly used.

Estimation from digestibility and fecal output

If digestibility of feed and the output of feces is known, intake can be calculated from the following formula:

$$\text{Intake} = \text{fecal output} \times \frac{100}{100 - \text{digestibility}}$$

This is currently the best method of determining intake, especially of individual animals. The preferred method of digestibility determination is in vitro digestion of samples collected from oesophageal-fistulated animals. Fecal output is measured either as total collection using a harness and bag or indirectly using insoluble markers such as chromic oxide. If chromic oxide capsules are administered and grab samples of feces are undertaken at correct intervals to provide a uniform distribution in the feces, total fecal output can be estimated from the amount administered and the concentration in the feces. Slow-release capsules giving even release for 21- and 90-day periods are now being tested and should greatly reduce the work involved.

This method could be further streamlined by using two or three oesophageal-fistulated sheep to provide samples for in vitro digestion and applying the digestibility so obtained to all the animals. Individual intakes would be estimated from individual fecal outputs.

Despite these advances, it should be realized that individual intake estimation requires considerable equipment and skill. It should not be undertaken without sound reasons.

ESTIMATION OF CARRYING CAPACITY

While carrying capacity is usually determined in practice by experience or trial and error, it is an advantage to be able to estimate it. At the theoretical level, carrying capacity can be estimated from dry herbage yield and daily animal feed requirement. The annual feed requirement of a 55-kg ewe and one lamb in New Zealand is estimated to be 550 kg dry matter (DM) of feed quality 10.5 MJ metabolizable energy (ME)/kg DM. A pasture with an annual yield of 11,000 kg DM/ha should be capable of carrying 20 ewes/ha. In practice, 12-16 ewes/ha can usually be carried. The discrepancy is because the efficiency of pasture utilization on a year-round basis is only 60-80% for sheep and goats. In the most efficient system (dairy farming), utilization may reach 85%.

A 20-kg ewe or doe in Asia producing 1.5 lambs or kids per annum and consuming herbage of 9 MJ ME/kg DM is calculated to require about 250-280 kg DM. Estimates of percentage utilization are not available, but assumptions could be made and the carrying capacity estimated. Obviously, estimates of carrying capacity based on herbage DM yield cannot be more than approximations, but they are useful, nevertheless, as a beginning and in causing one to seek reasons if large discrepancies occur between theoretical and actual values.

TREE CROP MEASUREMENT

There are no special techniques required for measuring the effect of grazing animals on the trees. In the early stages of tree growth, effects are simply measured as annual height or girth increase. Damage to trees is most likely to occur in young plantations because young or small trees are more susceptible to damage and because a greater density of stock is carried.

At later stages, yields of nuts, rubber, or palm oil, which are recorded, are the measures of animal effects. It is expected that, with the exception of damage, animals will have a beneficial effect on crop yield, through the more rapid turnover of soil nutrients and the control of weeds, and on costs, through a reduction of the labour and herbicide involved in weed control.

ANIMAL PRODUCTION MEASUREMENT

The final measure of herbage production and utilization is the production that grazing animals can attain and maintain. The difficulties of assessing animal production lie not in the measurement, but in the design, execution, and interpretation of the experiments. All that is required in measurement is a simple recording and analysis of vital statistics and weights (births, deaths, live weights, and dates of events). In the trials themselves, however, numbers of animals become important to enable some statistical assessment of reproductive performance and live weight gains, and to be representative of breeds in breed-comparison trials. Grazing-management studies, such as stocking rate trials, comparison of grazing methods, and cattle-sheep-goat comparisons, tend to be long term because of seasonal and long-range effects on pasture. The complex soil-plant-animal interactions make the interpretation of grazing trials especially difficult (Morley 1981).

Grazing trials, therefore, require considerable farm facilities in the form of area of land, number of animals, fencing, yards, and housing. They do not, however, require expensive laboratory facilities and equipment. In general, the conduct of experiments involving grazing animals is rather more difficult in the tropical environment than in the temperate zone and slightly more difficult again in tree crop plantations because the animal enterprise will have second priority to tree crop production.

Despite any difficulties, animal-production experimentation and data are vital to understanding any grazing system. Not only are they the final measures of the system, but field trials are the means of transferring basic knowledge into practice and of demonstrating new methods and technology to the industry. In the context of encouraging sheep and goat production under tree crops, relatively simple grazing trials should probably be given the highest priority.

CONCLUSION

The objective should be to develop sheep and goat management systems appropriate to the many variations within the plantation industry: from the smallholder with four to eight animals to the large estate owner with several hundred animals, and from the coconut plantation to the oil palm estate. For most situations, very little is needed. Very useful experimentation can be conducted on all these variations, provided some fencing is permitted and animals are available. Herbage yield, growth, feed preferences, tree damage, and animal live weight can be measured by research workers with the minimum of equipment. In many cases, this is adequate to identify problems.

Detailed grazing and animal studies require the facilities available at research stations and universities. These, or at least some of them, should have the capability of measuring in vitro digestibility, maintaining oesophageal-fistulated animals, conducting grazing-management studies, breed, and animal species comparisons. These should form the basis of demonstrating improved systems of integrated animal - tree crop production to the industry.

The following areas of research, in the opinion of the author, should receive priority.

- Fencing or other means of exercising pasture and animal control and the degrees and types of fencing acceptable and appropriate to different plantations;

- Establishment of animal production potentials or targets (at grazing) against which performance in villages or plantations may be gauged;
- Measurement of seasonal herbage growth and quality patterns and research on supplementary feeding to assist development of optimal animal management systems;
- Comparison of sheep only, goats only, and mixed flocks in terms of pasture and animal production, weed control, and damage to trees;
- Breeding methods to improve rate of gain of lambs or kids, including selection within existing breeds but especially use of exotic-indigenous crosses;
- Basic physiology of indigenous and exotic x indigenous animals in regard to general fitness to the environment; and
- Animal health problems, in particular, internal parasitism.

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A CONCEPTUAL FRAMEWORK FOR THE ECONOMIC ANALYSIS OF ON-FARM TRIALS WITH SMALL RUMINANTS

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Abstract *This paper provides a conceptual framework for economic analysis of small ruminant technologies at the farm level. Experience with small ruminants indicates that economic analysis should be conducted using both on-farm trial and experimental data. Special attention to the treatment of primary vs secondary benefits from small ruminants is highlighted. Issues related to costing of noncash inputs such as manure and family labour are briefly discussed. The importance of institutional economics to complement rigorous analytical methods is proposed.*

Economic analysis of small ruminant (SR) technologies at the farm level is a new subject. Although considerable experience has been gained with testing SR technologies at the farm level (Fitzhugh 1978; Knipscheer et al. 1984; Mukhebi et al. 1985; Sidahmed et al. 1985), these on-farm studies provide useful insights to improving SR productivity at the farm level. Most of this research concentrates on two aspects of SR production: nutrition and health. The testing of new feeds and supplements has proven useful in understanding farm problems and specialized mechanisms to approach the question of technology transfer in SRs (van Eys et al. 1985; Amir and Knipscheer 1986). Despite being successful, the economic implications of new technology are not fully understood. Besides problems related to a shortage of economists for analysis, there are difficulties in valuing noncash inputs and problems related to disciplinary bias. Technology is not designed to meet the particular farm groups; rather, it is tested on the farm based on the availability of technology at the research station. This is often true with new feed supplements and improved breeds.

Rarely do we gain a good understanding of the needs of the farmer or his demand for new technology. New approaches such as farming systems research (FSR) are reported to provide good problem definition through farmer participation (Bernsten et al. 1983; Sabrani et al. 1984; Knipscheer and Suradisastra 1986). However, FSR fails to specify the needed policy actions, which become the basis for change at the farm level. In the case of crop technologies, testing is often coordinated at the national level with direct participation from policymakers. Unfortunately, on-farm testing of SRs has received little policy support to increase productivity at the farm level.

This paper provides a conceptual framework to assist researchers in the economic analysis of SR trials. The micro- and macrolinkages between trial results and the final dissemination of the technology are considered important components of on-farm research.

A CONCEPTUAL MODEL

A realistic technology generation model should first define its client group. Unless the needs of the decisionmakers (small farmers, commercial and semicommercial producers, backyard producers, etc.) are identified, the technology proposed will rarely be accepted. This also implies that there is no single economic parameter that can be applied to all farm types. In other words, each set of farmers has differing objective functions and thresholds for accepting technology. This is different from saying that farmers do not adopt technology because it is risky. To illustrate, a feed supplement in Indonesia costing IDR 500 per month per animal (in 1986, 1626 Indonesian rupiah (IDR) = 1 United States dollar (USD)) appears cheap to the farmer who immediately sees the increase in animal weight and faces no cash constaint. Motivation for change, however, will depend on what the farmer plans or conceives he can do with a healthier animal. If there is a nearby market, it would be rational and desirable for the farmer to consider continuing with the new technology. In the absence of any foreseeable gains (as cash on hand is better than uncertain and minimal returns in the future), however, farmers would be reluctant to invest in the technology. This need not imply that the technology is inappropriate or not profitable. However, it does suggest greater caution in prescreening SR technologies at the research station prior to on-farm testing (Amir and Carlos 1986).

The various stages where economic analysis can guide researchers in identifying and analyzing new technologies are shown in Fig. 1. In many cases, it is better to develop simulated farm conditions on the research station to experiment with the technology. These demonstration farms (managed by farmers) are presently being used in India, Syria, and Malaysia to study the technical and economic efficiency of new treatments. This method can prove very cost effective. The response functions derived from such data can be studied in the light of farm conditions prevailing outside the research station. This approach, however, is not a perfect substitute for on-farm testing; the necessary prescreening should be carried out on demonstration farms, while technology verification should be done under real farm conditions. SR technology testing can be summarized in three stages.

Stage I

This stage is descriptive, where a good inventory of the farm problems with respect to SR production and marketing is studied. This stage should provide rough estimates of the economic value of existing production practices; it should also identify a hierarchy of SR livestock systems (i.e., commercial goat or sheep farms, small ruminants in a mixed-farm context, small ruminants on plantations). The institutional mechanisms that lead to grouping or production practices for different farm types should be noted. These may include, for example, groups of SR producers following a particular cropping pattern, composition of the farm family (usually SR kept by families with children), and sharing arrangements. The information collected at this stage (often through formal or informal surveys) should directly involve the technical scientists. Maximum use of secondary data is recommended. The researcher should get a chance to study the SR component as it exists on the farm rather than as it is "perceived to exist."

Stage II

The farm picture along with client needs (which will vary considerably) should then become the guiding principles of matching available technology to need, importing interregional technologies, importing potential technology not directly related to the problem at hand, and generating new technology through research. The linkage of stages I and II should be on a continuing basis; i.e., livestock researchers should regularly get involved in stage I to keep abreast of their client needs. Undoubtedly, the economist can provide useful

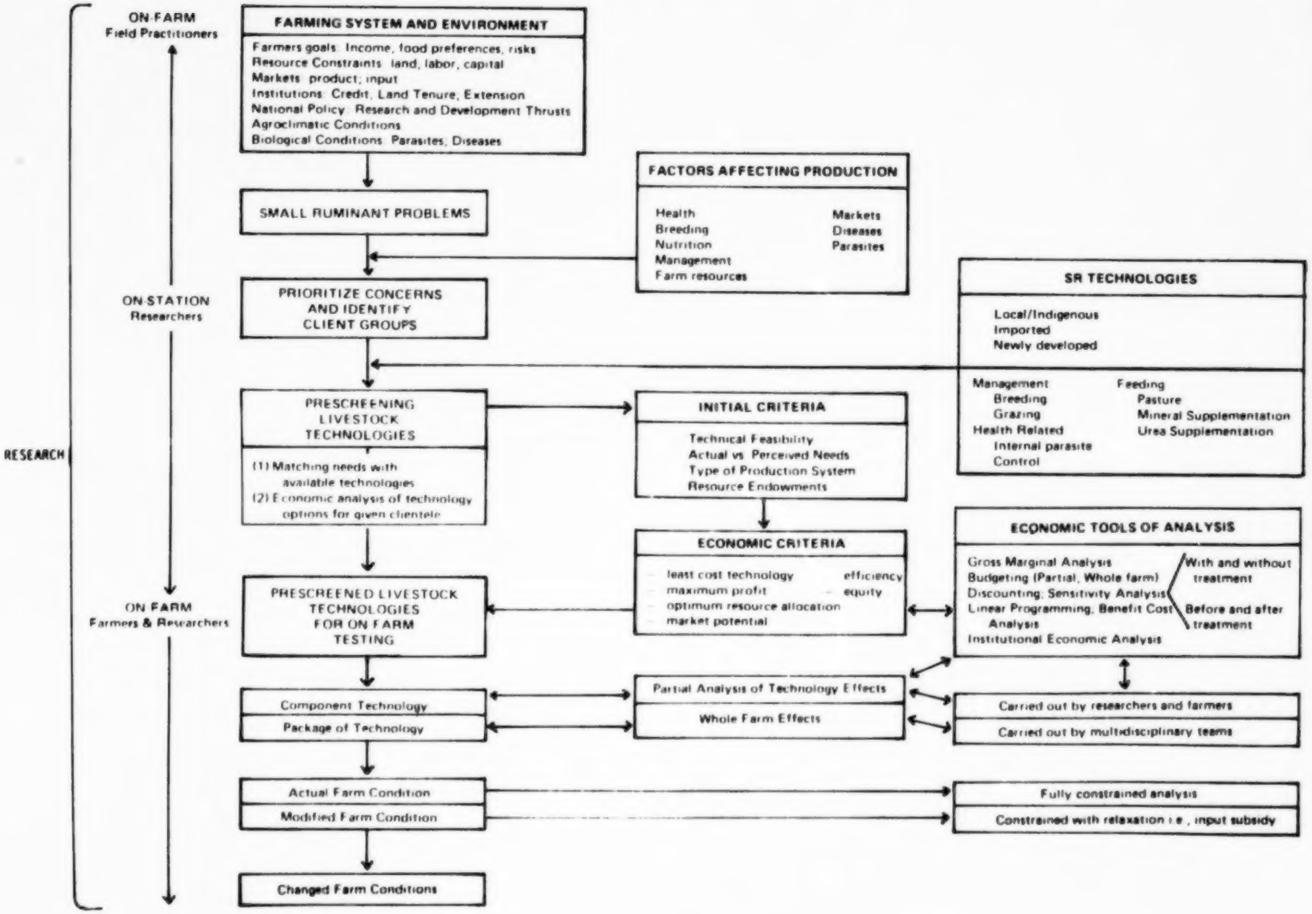
RESEARCH
ON-FARM
Field Practitioners
ON-STATION
Researchers
ON FARM
Farmers & Researchers
FARMING SYSTEM AND ENVIRONMENT
Farmers goals: Income, food preferences, risks
Resource Constraints: land, labor, capital
Markets: product; input
Institutions: Credit, Land Tenure, Extension
National Policy: Research and Development Thrusts
Agroclimatic Conditions
Biological Conditions: Parasites, Diseases
SMALL RUMINANT PROBLEMS
FACTORS AFFECTING PRODUCTION
Health
Breeding
Nutrition
Management
Farm resources
Markets
Diseases
Parasites
PRIORITIZE CONCERNS AND IDENTIFY CLIENT GROUPS
SR TECHNOLOGIES
Local/Indigenous
Imported
Newly developed
Management
Breeding
Grazing
Health Related
Internal parasite Control
Feeding
Pasture
Mineral Supplementation
Urea Supplementation
PRESCREENING LIVESTOCK TECHNOLOGIES
(1) Matching needs with available technologies
(2) Economic analysis of technology options for given clientele
INITIAL CRITERIA
Technical Feasibility
Actual vs Perceived Needs
Type of Production System
Resource Endowments
ECONOMIC CRITERIA
– least cost technology
– maximum profit
– optimum resource allocation
– market potential
– efficiency
– equity
ECONOMIC TOOLS OF ANALYSIS
Gross Marginal Analysis
Budgeting (Partial, Whole farm)
Discounting; Sensitivity Analysis
Linear Programming, Benefit Cost Analysis
Institutional Economic Analysis
With and without treatment
Before and after treatment
PRESCREENED LIVESTOCK TECHNOLOGIES FOR ON FARM TESTING
Component Technology
Package of Technology
Partial Analysis of Technology Effects
Whole Farm Effects
Carried out by researchers and farmers
Carried out by multidisciplinary teams
Actual Farm Condition
Modified Farm Condition
Fully constrained analysis
Constrained with relaxation i.e., input subsidy
Changed Farm Conditions

Fig. 1. A conceptual model for small ruminant economic analysis.

input in prioritizing research problems based on existing research resources and help in developing realistic research designs relevant to different farm situations. In addition, the economist can assist in developing hypotheses about the consequences of various technologies, based on their economic profitability. This input to research can be invaluable in technology choice. The market implications of the technology should take absolute priority. Whether the new technology is consistent with the goals of government policy also becomes important. Addressing some of these basic issues will help in a realistic appraisal of the new technology and increase its chances of success.

Stage III

Once a careful analysis of the technology requirements of the clients is made and suitable technologies have been screened for on-farm testing, economic analysis should be held back to allow livestock scientists maximum freedom in testing the technology. The guiding principle here should be to observe and record the "with and without effects" or "before and after effects" of interventions. The results of the technology testing should be studied for their economic viability.

IDENTIFICATION OF COSTS AND BENEFIT

It is important that costs and benefits of the technology be identified through on-farm performance. Often, this is relatively simple, especially the identification of cash inputs. Noncash inputs such as family labour, forages, and household wastes, however, are difficult to cost. Moreover, experience shows that it is easier and perhaps more relevant to develop budgets for SR herds than to estimate cost per animal (Carkner et al. 1981; Amir et al. 1986). In deriving partial budgets, gross margins, and cost of production estimates, many relevant costs and benefits must be considered (Table 1). Valuing of benefits is crucial, as there is a tendency to overvalue benefits, which may lead to erroneous conclusions. Determining the field price of inputs and outputs can become a difficult exercise. It is important to know whether animals should be valued on a live-weight basis or on physical inspection (the latter is often the case). Therefore, knowledge of the market is essential in the evaluation of technology. Similarly, caution should be exercised in costing inputs such as labour (Price 1982). Often, the marginal cost of an additional animal is negligible in terms of care and management,

Table 1. Breakdown of benefits and costs for economic analysis.

Benefits	Costs
Primary	Primary
Increase milk yield	Cash costs
Increase litter size	Feed costs: hay, salt and minerals, concentrates, grains, feeds for the young
Culls (ewes, rams, does, bucks)	
Goat meat and lamb or mutton	
Mohair and wool	
Hides	Nonfeed costs: veterinary, medicine and drugs, vaccine
Manure	
Horn and hooves for processing into feed supplements and other products	Wages for hired labour
	Pasture rent
Meat and milk by-products	
	Noncash costs
	Family labour
	Interest costs
Secondary	Depreciation (of facilities, of equipment, etc.)
Urine	Other nonmarket feed costs
Weight increase (realized when the animal is sold)	
Size and weight increase	
Weeding-grazing	Secondary
Farmers' preference	Carry disease
Attractiveness of colour and appearance	Destruction of crops, trees, etc.
Religious purposes	Trampling of land (which causes ecological imbalance)
Pet	
Entertainment	
Seed distribution	Foul odour
Research	Noise pollution

especially under traditional management systems. In cases where a new technology requires giving the treatment individually (i.e., vaccination), the labour input should be valued at its opportunity cost. Care must be exercised to differentiate between "leisure labour" for activities such as watering, giving medicine, mating, and feeding, and "hard labour" required for agricultural operations such as ploughing, transporting grain, and transplanting seed (Amir et al. 1986). The latter require more skill and energy. Therefore, it is not appropriate to cost 1 h spent in SR management at the same rate as 1 h spent in hard labour. Similarly, labour wages should not be unnecessarily discriminated on the basis of age or sex of the labourer.

In the case of SRs, four products are considered important by farmers: reproductive capacity of animals, animal mortality, ability to gain weight, and milk production. Valuing these variables becomes important as farmers are interested in knowing how the new technology will influence these variables and with what degree of risk. Valuing minor benefits such as manure should not be ignored. In Indonesia, farmers make special use of SR manure for growing cloves. Where market price is not available, manure can be attributed a value equivalent to the reduced use of artificial fertilizer (inclusive or transportation charges).

TECHNOLOGY PERFORMANCE AND PROFITABILITY

The performance of new cost-reducing technologies such as supplements, introduction of new breeds, medicines, and husbandry practices should be judged in light of the performance at the research station. The idea is to verify research station results and to develop hypotheses for inducing change based on economic profitability. A technology may be reasonably profitable and successful on the farm, but may not gain acceptance among farmers. Two questions are worth posing. First, what are the marginal returns to investment in the new technology compared with alternative investments and are alternatives available that carry more weight in the farmers' portfolio? Second, is the technology not being adopted because it carries high risk, deviates too much from the traditional practice, or is unavailable from the local shop?

It is important to recognize that the goals of on-farm livestock testing is to verify technology performance and profitability. Acceptability is often related to the environment (physical, social, political, and biological). Often, mass acceptability will require government support through input subsidy, providing incentives to cover risk in the earlier stages and expressing support through price and tax concessions. Developing testable hypotheses on the possible effects of these instruments can become an important part of on-farm livestock research (Amir et al. 1985; Amir and Knipscheer 1986).

TECHNOLOGY CHOICE AND ECONOMIC ANALYSIS

In the evaluation of SR technologies, the choice of analytical tool is important. This choice should depend on the skills of the analyst, the availability of data, and the resources at hand. The various studies cited in this paper have used many different analytical tools appropriate for a partial evaluation of the new technology (Table 2). The usefulness of these tools for analyzing on-farm livestock trials has been discussed in detail elsewhere (Amir et al. 1985).

Partial budgets (Table 3) are appropriate for analyses of single interventions, such as effects of a mineral supplement on the milk yield of goats. The tool is simple enough to be used by field practitioners with a limited knowledge of economics and statistics. Caution should be exercised in deriving field prices and in costing joint inputs.

When the analyst wishes to study interactions among different farm components (crops, livestock, off-farm opportunities, etc.), however, he or she must resort to mathematical programming (linear, quadratic, multiperiod, goal, etc.). These analytical models allow considerable flexibility for whole-farm analysis. In addition, recent developments in simulation methodology have made some important livestock production problems easier to handle: i.e., risk, mobility, joint products, and growth synchronization. The wide availability of low-cost microcomputers provides ample scope for developing spread-sheet simulation templates that can be used for developing farm models and simulating conditions under alternative price, yield, and policy scenarios. A simplistic illustration of such a spread-sheet template has been discussed by Hart and Knipscheer (this volume).

In cases where SRs are being introduced for the first time, special attention should be given to the cash flow. The data needs of the analytical model should be spelled out during the design phase of on-farm experiments. The analysis should reveal existing profitability of the treatment or package of treatments based on local price conditions. Merely reporting

Table 2. Proposed economic tools for different types of on-farm trials.

Small ruminant treatment	Variable	Approach
Breeding management	Fertility, kidding interval, no. born per parturition, no. of parturitions per lifetime	Gross margin analysis, discounting
Health related	Fitness, incidence, and cause of morbidity and mortality, parasite infestation	Benefit-cost analysis, partial budgeting
Feed supplementation	Weight gain, growth in size and height, morbidity and mortality rate	Benefit-cost analysis, partial budgeting
Range and improved forage management	Weight gain, fitness, milk yields	Discounted cash flow analysis, partial budgeting, gross margin analysis, sensitivity analysis, financial analysis
Rearing management	Milk intake, growth in size, height, and weight, morbidity and mortality	Benefit-cost analysis

whether the technology is profitable does not provide much information to the technical scientist. The analysis should go one step further and outline what changes in the environment (price, subsidy, market, taxation, education) will be required

Table 3. General format of the partial budget.

Debits	Credits
A. Additional costs B. Reduced receipts	C. Additional receipts D. Reduced costs
Incremental costs Marginal net benefit	Incredmental benefits B:C ratio or absolute marginal rate of return

before the technology will have a reasonable chance of success. These questions fall in the domain of institutional economics, which requires the study of local institutions to identify the behaviour of farmers as a group.

TRAINING NEEDS FOR ECONOMIC ANALYSIS OF SR TRIALS

Given the acute shortage of livestock economists at research stations, it is necessary that livestock specialists acquaint themselves with basic economic analysis. This skill includes developing enterprise budgets, conducting marginal analysis, benefit-cost analysis, determining market potential, and identifying constraints. Skills for the type of analysis can be imparted through short courses. For more advanced analysis of the whole-farm consequences, it is recommended that the services of a professional economist be sought.

CONCLUSIONS

This paper has argued for the need to conduct economic analysis both on experimental and on-farm livestock trials data to determine the profitability of new small ruminant technologies. A conceptual framework is proposed that can assist researchers in the economic evaluation of new technology. It is argued that mere good performance and profitability of the technology is not sufficient. Valuation of costs and benefits related to small ruminants is discussed. The need for a strong policy commitment to improve small ruminant performance is identified as a prerequisite for increasing productivity. This implies that a sensitivity analysis based on different socio-economic and government policy assumptions be included in the analysis.

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DISCUSSION

The final session dealt with the important question of future strategies and research methodology appropriate to small ruminants. Five papers were presented in this session. The session opened with two papers on strategies for the development of small ruminant productivity. Firstly, Drs Bradford, Subandriyo, and Iniguez considered breeding strategies, and then Dr Devendra discussed strategies other than breeding.

Dr Bradford stressed the well-known but too often ignored fact that we need an animal genotype to match the environment. The standard of the environment must be improved, especially the nutrition, to use improved genotypes. There are three approaches to improving the genotype:

- Selection within local breeds: One important aspect of this approach is that it utilizes the adaptability of the local animals; it also gives products that are known and are marketable. This type of selection, however, will give only a slow rate of genetic improvement.
- Importation of breeds for crossing: This approach can give rapid genetic progress, but it must be ensured that the crossbred animals are suitable.
- Importation of improved breeds together with the technology for their production: This is not usually a viable approach for sheep and goats where small producers are unable to maintain an environment good enough to support the new breeds. Even though importation may increase growth rate, long-term reproductivity is likely to be low.

Dr Bradford also discussed the assessment of a breed adapted to an environment and gave practical standards in terms of reproduction, growth, and mortality.

The discussion included a debate on whether sheep and goats can alter their productivity according to the environment. It was thought that animals cannot manipulate their basal metabolic rate according to the stress of the environment, but examples were cited of Scottish Blackface sheep that give one lamb in the hills but twins when they were in more favourable lowlands. The Finnish Landrace appears not to be able to do this; it always produces multiple births.

Other points considered were that selection in villages could concentrate on twin births and animals with little wool cover, but not for growth rate, which is negatively correlated with litter size. Big animals are not necessarily the best.

In the second paper, Dr Devendra stressed the need for production objectives. What exactly do we want to produce: is it meat, milk, meat and milk, skin, fibre, or a combination of these? He emphasized the need for this definition. The relative advantages of sheep and goats must be considered in the context of availability and quality of feed resources, feeding behaviour, availability of animals, survivability, relative price of meats, market outlets for meats, and biomass production.

He isolated two systems that have the greatest potential for development: intensive stall feeding and integration with tree crops. With the second system, he illustrated how the current population of goats and sheep can be increased by 66-86%, which can make a major impact on production. The most important single factor that limits production was identified as nutrition. Dr Devendra thus stressed the importance of nutritional strategies. These included increased utilization of crop residues and agroindustrial by-products, nonconventional feeds, increased forage cultivation on available land, increased dietary nitrogen, use of urea-molasses block licks, and strategic use of high-protein concentrates. Of the available options, he emphasized clearly the importance and value in the use of a variety of leguminous forages throughout Asia such as Leucaena or Sesbania. Dr Devendra also emphasized the need for more intensive systems of production, resource allocation, research needs, and possible commercialization and recommended that export markets be exploited and that research, development, and particularly extension services be given much more attention.

The utilization of molasses and sugarcane by-products was discussed. Levels of molasses beyond 20-30% are not normally used and will cause problems of diarrhea. Dr Devendra was not aware of any work involving goats using high levels of molasses parallel to the efforts in Cuba of feeding molasses to cattle.

This paper did not consider areas of health and other aspects of management in detail. These areas also need attention in seeking improvements in productivity.

The third paper concentrated on research methodology. Dr Pattie described and discussed the farming systems research (FSR) approach that is being used by many agricultural scientists. His talk concentrated on the later stages of FSR, i.e., trying to find improvements. He stressed the problems of trying to conduct comparative experiments in the field. If we work on farms, we know our results will be applicable to the situation, but it is very difficult to do scientifically significant experiments unless these are very simple. In particular, there are problems in obtaining replications. Dr Pattie gave examples of incorrrect statistical analysis of on-farm breeding and management experiments and suggested that, in many cases, no statistical analysis would be preferable (although not usually acceptable to journal editors!). Large differences are often instantly visible. Dr Pattie also stressed the importance of reproductive rate in determining the ability of a population rate to expand and in determining its productivity.

In the fourth paper, Professor Coop discussed research methodology for small ruminants in integrated systems with tree cropping. He reviewed the methods and techniques available for measuring herbage production and utilization and animal production under tree crops. The techniques for these measurements have mostly been developed and shown to work well in developed countries. The design, execution, and interpretation of grazing experiments require care. The objective of research must be clearly known; if only simple answers are required, the experiments can and should be kept simple.

The final paper of the workshop by Dr Amir considered the economics of on-farm trials. If a new technology is to be acceptable, it must be economic. At present, however, there are very few livestock economists working in tropical Asia. Scientists other than economists are likely to have to conduct economic analyses and Dr Amir summarized the different analytical tools available.

The discussion covered the importance of matching the farmers' needs to the technology available. Initially, a technology given to the farmers must be available at no cost and requiring little extra effort. Later, as the technology is adopted and accepted, the farmer becomes willing to pay at a level they consider will allow them to make a profit. Finally, Dr Amir observed that the leadership for transfer of technology to the villages seems to come from research scientists rather than from extension workers; thus, the research scientists are responsible for initiating these improvements.

Conclusions and Recommendations

The conclusions and recommendations of the workshop were the result of four working groups on all aspects of small ruminant production systems. Participants were grouped according to systems, namely extensive, intensive, and systems integrated with the cropping. A fourth group dealt with research priorities and methodology.

In integrating the individual group recommendations into one final report, it was decided that it would be more meaningful to address these recommendations by discipline. This enabled issues to be presented across systems. The emphasis will, of course, vary with some systems such as the intensive or integrated tree cropping systems. Although the recommendations are compartmentalized into disciplines, it is emphasized that these should be integrated into a multidisciplinary effort, especially on whole-farm systems during the process of on-farm research involving both crops and animals. There should be continuous and concurrent monitoring of results at both the experimental and the farm levels.

The following summary of the recommendations represents the overall consensus of the workshop in terms of the most important priority areas.

FEED RESOURCES

Forages

The introduction, evaluation, and management of forages is influenced by a number of factors, especially the type of system (smallholder vs large commercial producer), agroecological zone, and the potential for integration with food crops.

The production and utilization of native and especially cultivated forages offer the potential for large increases in dry matter production, carrying capacity, and animal production. To date, most research has concentrated on the utilization of these forages by cattle and there is now a need to examine utilization by small ruminants.

The criteria for choosing specific species or cultivars for introduction will be similar to those for normal plant introductions such as soil type, fertilizer requirements, dry matter yield, persistence, etc. In addition, the following aspects merit special consideration with reference to small ruminants: selectivity, feeding behaviour, capacity to utilize poor-quality forages, and pasture and weed control. It is recognized that small ruminants have a smaller capacity to consume low-quality pastures.

The important steps necessary in the introduction of grass or legume species are

- Screening of species and cultivars (introduction garden);
- Cultural trials with a few promising species or cultivars (replicated treatments);
- Nutritive evaluation (total cell wall or neutral detergent fibre (NDF), crude protein, palatability) in a controlled feeding trial;
- Effect of the animal on the sward (persistence after controlled grazing);
- Animal management trials, after all agronomic practices have been established, to determine animal productivity in relation to grazing management; and
- Large-scale propagation for field trials under commercial conditions.

Some of the grass, leguminous, and broadleaf species that show promise include, respectively, _Panicum maximum_, _Seteria splendida_, _Pennisetum purpureum_, _Brachiaria decumbens_, _B. milliformis_, and _B. brizanthia_; _Centrosema pubescens_, _Stylosanthes_ spp., _Desmodium heterophyllum_, _Leucaena leucocephala_, _Sesbania grandiflora_, _Gliricidia_ spp., and _Erythrina_ spp.; and _Milkania_ spp.; and _Assytasia_ spp.

With specific reference to plantation crops, there is a need to study the existing herbage in terms of quality, yields of dry matter, intake and palatability, toxic components, and seasonality of production. These factors will vary with type and age of primary crops such as coconuts, cocoa, oil palm, rubber, and cashew.

Leguminous Tree Forages

There is increasing evidence that leguminous trees, e.g. *Leucaena leucocephala*, can play an important role in animal nutrition. As an important component in the diet, they supply protein, especially in systems involving low-quality fibrous feeds. Their multiple uses include fencelines and fuel, and, with reference to small ruminants, they make a valuable contribution to feed supply throughout the year. The production and wider utilization of these forages at the farm level merits high priority.

Crop Residues, By-products, and Nonconventional Feeds

The workshop recognized the existence of a wide variety of crop residues, by-products, and nonconventional feeds such as sorghum straw and sugarcane tops, and recommended more intensive utilization of these. With reference to plantation crops, these feeds included coconut meal from coconuts; palm press fibre, palm kernel cake, and palm oil mill effluent from oil palms; and rubber seed meal from rubber. The workshop supports the current research programs in individual countries that have an important relevance to improved feeding systems for small ruminants.

Supplementation

The low feed values of tropical forages create a need to supply supplements if reasonable levels of animal production are to be achieved. The priority areas requiring research are

- The inclusion of high nitrogen materials (e.g., tree legumes) in the diet;
- Mineral deficiencies and methods for detecting these under local conditions;
- The strategic use of supplements for lactation and during drought periods; and
- The economic use of high-energy supplements to maximize live weight gain in young animals being prepared for market.

Fodder Conservation

To even out the seasonal feed supply, there is a need to be able to preserve forages in times of plenty, such as in the wet season, for utilization in the dry season. Hay and silage making, common in the temperate zone, is exceptional in the tropics.

It is recommended that special attention be given to research into methods of very small-scale conservation and storage, either by sun drying or as silage. This should apply to both pasture forages and tree leaves.

Effect of Animal Integration on the Parent Crop

A wide variety of issues must be considered in this complex interaction. The following are listed in no particular order of priority and are meant to be examples rather than an exhaustive list.

- Possible damage to leaves or bark of the primary tree by the grazing or browsing animal: greater precautions must be taken in introducing goats in rubber plantations because of possible damage to the bark; young trees are likely more susceptible to browse damage, as may be the new dwarf coconut hybrids;

- The beneficial effect of the animal in weed control, sparing herbicide use and cost: the complementarity of animal and chemical weed control must be studied;

- Beneficial effect of the animal in browsing lower, senescent leaves;

- Possible transmission of plant diseases from pasture plants to the trees;

- Soil compaction by grazing animals;

- Soil organic matter and N fertilizer from animal excreta;

- Soil moisture depletion by the forage crop; higher evaporation rate if ground cover is overgrazed;

- Animal damage to latex collection cups with rubber cultivation; and

- Possible reduction of rodent population (important in oil palm plantations) under grazing.

Recognizing these points, the workshop recommended research be conducted into the variety of possible effects on the parent crop.

- Intensity of grazing and carrying capacity;
- Possible alteration of the normal planting density of the primary tree crop to accommodate a longer productivity from the herbage;
- Optimum times for introducing the animals for specific tree crops in agronomic and economic terms; and
- Dual-purpose value of the legume cover for the animals and the plantations.

Effects of Primary Crop Management on Small Ruminants

The following issues are relevant concerning the effects of primary crop management on the animals. These issues merit continuous monitoring and research as appropriate.

- The residual effect of herbicides (contact vs systemic) and its duration;
- Adjusting grazing rotations to cultural and harvesting practices, for example, in possible consumption, indigestion and death of the animals as a result of latex consumption in rubber;
- Problems of metabolic disorders are also likely in the ingestion of fruitlets of oil palm fruit bunches;
- Possible effects in areas where rodenticides have been used; and
- Presence of toxic compounds in forage plants when processing effluents (e.g., palm oil mill effluent) on the land and in streams; there is also the effects of oil palm by-product build-up.

BREEDING

There is a great need to improve the productivity of goats and sheep in the region. While nutrition and disease control may be the most important influences, the breeding of animals that are more productive in the local environment is also important. In the past, most attention has been given to introduction by crossbreeding of genes from supposedly higher producing stock from temperate zones. Emphasis is now shifting towards selection within local breeds. It is felt that this deserves as much if not more emphasis.

The following recommendations are considered important:

- Definition of production objectives (meat, milk, fibre, skins, or a combination of these).

- The evaluation of the characteristics and potential productivity of local breeds should continue.

- Where practicable and within the most important breeds, there should be a moderate to large-scale screening of individual animals in smallholder flocks for specific performance traits. These animals should be tested against randon samples and, presuming that the selected group will be superior, it should then form the nucleus for breed improvement and subsequent supply of sires to smallholders.

- In line with the evidence that crossbreeding to upgrade local animals is a practical proposition in a number of regions and circumstances, research on introduction and crossbreeding should continue. At the same time, there is a need to ensure that adequate and fair comparisons be made with local animals before concluding that crossbreeding outweighs the advantages of selection within local breeds. In certain cases in the past, the evidence is clear that crossbreeding confers definite advantages, while in other cases, the advantages are of doubtful validity. It is, therefore, necessary to give greater consideration to objectives, especially in the choice of breeds and in implementation with respect to representativeness and the scale of the operation.

- In breed comparisons, total productivity over a life time should be the basis of comparison rather than just an individual component. This should include research on various products (meat, milk, fibre, and skins).

HUSBANDRY AND MANAGEMENT

It was obvious that there was a wide variety of animal husbandry practices that affect animal performance and production. Many aspects were discussed and the following were highlighted as important areas for research.

- There should be a comparison of the economic and production advantages of seasonal controlled breeding versus nonseasonal uncontrolled breeding. Issues involved are management of labour problems, marketing constraints or advantages, and the matching of feed demands with feed supply.
- The management of unweaned kids and lambs should be examined. The possibility exists for reducing the mortality of unweaned animals through keeping young animals confined until weaning.
- The value of differential feeding for different classes of stock compared with the common practices of feeding all animals the same diet should be determined. Different classes of animals have different feed requirements in terms of quantity and quality.
- Alternative methods of grazing should be examined, both in terms of animal performance and in terms of capital and labour requirements in semi-intensive systems.
- There should be an investigation of efficiency of labour use through time and motion studies and a consideration of options available for decreasing the labour requirement of intensive animal production systems. For example, the sowing of cultivated forages close to the house, the benefits of less frequent feeding on animal performance, etc.
- Fencing or shepherding of animals will be influenced by costs, labour availability, and, on large estates, requirements for the movement of machinery.
- Methods of control to reduce predation.

HOUSING

In view of the general necessity to house animals either totally or at night only, the capital cost is an important item of the whole enterprise in both smallholder and large commercial operations. Smallholders generally use local materials (wood, bamboo, thatch, and, occasionally, corrugated iron or tiles), while large commercial units tend to have a concrete base, milled timber flooring, and iron roofs.

It is recommended that a thorough study be made of the following:

- The optimum design for housing, including, for example, type of flooring and slat arrangements, feed and water troughs, ease of feeding and cleaning, ventilation, and the strength, life, and maintenance of materials. The designs should include consideration of engineering, animal management, and environmental conditions for the animals, such as draft-free areas for young animals.
- The cost effectiveness of the various types of design.

HEALTH AND DISEASES

Disease is a major constraint to production in most countries of the region. While in intensive systems of management, diseases can spread more rapidly, the control of diseases can be more easily implemented.

Diseases of known major importance include endoparasites (especially in grazing systems), ectoparasites (e.g., scabies), and respiratory diseases such as pleuropneumonia. Surveys supervised by veterinarians will determine the relative local importance of other diseases such as melioidosis, nasal worms, cerebrospinal nematodosis, Escherichia coli, coccidiosis, contagious ecthyma, and conjunctivitis.

Further research is needed on the epidemiology of specific diseases. Appropriate recommendations must be locally developed for vaccination programs, drenching schedules, and other control measures. Particularly for smallholders, some form of government subsidy for disease control campaigns will be necessary. Support services that provide education materials, vaccines, diagnostic services, etc., must be given proper attention.

An awareness of nutrition-related diseases and toxicity problems must be developed. The avoidance of introducing exotic disease organisms is a top priority. Traditional medicinal herbs could profitably be evaluated more systematically.

The following recommendations were considered appropriate:

- The economic costs of disease in all classes of animals in all types of production systems should be assessed since chronic disease can cause a large economic loss. This may be more important than control of mortality.

- There is a need for a more extensive diagnosis of reasons for mortality. There should be a survey by veterinarians to better identify the major causes of mortality, especially in young animals.

SOCIOECONOMIC ISSUES

Socioeconomic factors play a dominant role in the life of all those involved in the agriculture sector. The implementation of any recommendations arising from research and extension should meet the desires and aspirations of the flock owner and his family.

With special reference to small ruminants, the role of the family, especially women and children, is dominant, much more so than with other ruminants. The magnitude of this, however, remains largely unknown.

To this end, there is a need for continuing research on the economic value of any new development and the effect of new developments on family members. This research would be carried out by economists and other social scientists.

The role of women and children must be examined more closely. Who makes the management decisions? Who carries out various management practices? Do daily feeding and herding chores interfere with or complement the schooling of children?

Economists can help farm managers, large or small, evaluate the costs and returns to alternative practices. One basic choice to be made is between food crops and forages as the understory for small tree-crop plantations. Alley systems, multitiered systems, rotations, and fencerow tree legumes are among the many options. At the macrolevel, government policies and priorities have an influence. The following issues, among others, must be dealt with immediately: adequate support to research and extension, adequate marketing information, the possible role of cooperatives, and timely provision of credit.

DEVELOPMENT AND RELATED ISSUES

Increasing productivity from small ruminants in the future will require much more emphasis on on-farm research and development. It will require a consideration of the type of work to be undertaken, whether it is realistic or pragmatic, the applicability to small farm situations with scarce resources, and the extent of resource allocation necessary to support the work. In consideration of these, the group made the following recommendations:

- Trials should be simple and based on a pragmatic approach.
- Difference between research- and extension-based trials should be clearly recognized. Objectives of the trials should be directed at meeting the needs of a particular recommendation domain.
- Necessary logistical support, financing, technical, and field support should be provided.
- Realistic measurement of variables should be predetermined. Equipment and instrumentation used for measurement should be light and transportable.
- Design of trials should take into consideration the variability within species, agroclimatic zones, farm size, income groups, etc. Distinctions should be made with regards to the measuring of impact, i.e., physical observation versus actual weighing, the difference between experiment station and on-farm results, and the technical and economic relevance for different farm groups.
- Trends in analysis that give greater precision should be recognized. In the meantime, the general rule of thumb is five farmers (to 30-40 animals), with the same number as a control, five perhaps located in one or two villages to economize on cost (i.e., travel, etc.). Researchers should not be afraid to compromise. Even if technology is in a preliminary stage (but shows promise), it should be

considered for on-farm testing. Often, researchers are scared of being exposed, at times spending resources on projects which they initiated for their PhD work.

- On-farm research is a relatively new field. It requires policy commitment and continuous support from donors and government. Impact is directly related to these components. The international donors should be encouraged to sharpen their development focus in that direction.
- On-farm trials should be conducted in the context of farming systems research. This must involve the participation of farmers. Experience to date indicates that a component approach should be further experimented with.
- Need for a technology transfer unit with each research institute. On-farm testing should be an integral part of the research program.
- Research on small ruminant diffusion models is necessary.
- Market potential for each country, region, and subdistrict should be realized prior to testing. The analytical procedures should be explained to all on-farm researchers.
- To facilitate the publication of on-farm research results, the participants recommended that editorial policy be influenced to widen publication opportunities.
- Information sharing through dissemination of print and nonprint materials relating to research, extension, and development work within the region is almost completely lacking among developing country groups and the various agencies involved in small ruminant research. An initiative is urgently required to establish an information system that would enable small ruminant workers to have a vehicle for communicating information (e.g., newsletter); a methodology for reporting print or nonprint and published or unpublished regional literature; a channel for publishing on-farm research results; and a means of identifying and commissioning the preparation of special-purpose handbooks (e.g., list of projects in progress, disease incidence in the region, genetic data base).

The meeting had the advantage of a discussion with two representatives of the Food and Agriculture Organization of the United Nations (FAO) engaged in facilitating the advancement of small ruminant production. The discussion centred on an inventory of all ongoing projects (research, development, training) and the initiation of in-country, integrated training courses for extension staff in practical on-farm development strategies. The meeting unanimously endorsed these proposals.

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